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on

Coral Reefs in the Coastal Waters of the South China Sea

MALAYSIA

Jabatan Perikanan Malaysia

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MALAYSIA

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INTRODUCTION

Malaysia's coral reefs extend from the renowned "Coral Triangle" connecting it with Indonesia, Philippines, Papua New Guinea, and Australia. Coral reef types in Malaysia are mostly shallow fringing reefs adjacent to the offshore islands. The rest are small patch reefs, atolls and barrier reefs. The United Nations Environment Programme's World Atlas of Coral Reefs prepared by the Coral Reef Unit, estimated the size of Malaysia's coral reef area at 3,600sq. km which is 1.27 percent of world total coverage (Spalding *et al.*, 2001).

Coral reefs support an abundance of economically important coral fishes including groupers, parrotfishes, rabbit fishes, snappers and fusiliers. Coral fish species from Serranidae, Lutjanidae and Lethrinidae contributed between 10 to 30 percent of marine catch in Malaysia (Wan Portiah, 1990). In Sabah, coral reefs support artisanal fisheries but are adversely affected by unsustainable fishing practices, including bombing and cyanide fishing. Almost 30 percent of Sabah's marine fish catch comes from coral reef areas (Department of Fisheries Sabah, 1997). However, landings in Sabah have declined since the 1980s due to destructive fishing, particularly, blast fishing (Cabanban, 1999).

The supply of live reef fish from Sabah to Hong Kong is dependent on wild stocks. The Trade Record Analysis of Flora and Fauna in Commerce (TRAFFIC) reported that Hong Kong is the largest importer of live reef fish, consuming 25,000 tonnes annually and re-exporting another 5,000 tonnes to mainland China (TRAFFIC, 1999). In 2001, the International Marine Life Alliance (IMA) recorded a total of 3,212kg of Napoleon wrasse imported to China from Malaysia. According to IMA, this data may represent under reporting of total catches from the area because many vessels operating in the area are from Hong Kong and do not declare their landings. Cyanide fishing, which is hazardous to coral reef ecosystems, is probably used in catching the live coral fish.

Coral reef related tourism provides revenue for the national and state governments in Malaysia. A significant work force is engaged in this tourism sub-sector and associated activities such as hotels and resorts. Marine recreational activities that consist of diving and snorkelling have great value in the coral reef tourism industry. In 2003, a informal report estimated that Conservation Charges collected for entrance to Malaysia's Marine Parks amounted to RM1 million . The same report also revealed that the marine parks attracted 778,482 foreign and 820,116 local tourists. Realising the potential pitfalls of ecotourism, some marine parks such as the Sabah Parks applies the multiple-use concept to attract tourism in marine parks. This concept promotes different uses of the marine park depending on the environmental quality and tourist interest (Cabanban and Nais, 2003).

Fragile coral reefs are threatened by man-made and natural phenomenon. Sedimentation, pollution, indiscriminate anchoring, and destructive fishing are the major anthropogenic causes of damage in coral reef areas. In Malaysia, destructive fishing such as fish bombing and cyanide fishing are rampant in Sabah. Trawling which is equally destructive to coral reef occurs in Mersing.

Natural causes of coral reef damage are diseases, predators and global climate change. To date, no research has been carried out to determine the occurrence of coral diseases in Malaysia. However, yellow and white band diseases have been observed respectively in Langkawi and Port Dickson (The Star, 2005; Berita Harian 2005; Yang Amri, pers. com.). Another harmful biological agent is the notorious coral predator, the crown-of-thorn starfish (*Acanthaster planci*), which is reported to have caused significant damage to coral reefs in Pulau Redang in the late 1970s.

Global climate change has been identified as the most recent and significant threat to coral reef ecosystems. The Global Coral Reef Monitoring Network (GCRMN) provides data on coral reef status linked to global climate change for research and monitoring purposes. It was reported that 16 percent of the world's coral reefs were affected by rising sea temperature during the extreme El Niňo Southern Oscillation (ENSO) event between 1997 and 1998 (Wilkinson, 2002). Slight temperature anomalies of 1-2°C above or below the normal threshold can cause coral bleaching. During the 1998 ENSO, sea surface temperature in the South China Sea increased by 2-3°C above the normal threshold (Wilkinson, 2002). Consequently, coral reef areas in Pulau Payar on the west coast of Peninsular Malaysia, as well as coral reef areas in East Malaysia have been impacted by coral bleaching (Pilcher and Cabanban, 2000).

This national coral report aims to review the status of coral conservation in Malaysia based on the national coral reef meta-database, updated information, and management perspectives.

CORAL REEF DISTRIBUTION

Of the 3,600km^2 of coral reefs area in Malaysia, important coral reefs are found in Sabah and the east coast of Peninsular Malaysia. Almost all of the islands in southeast, central, northeast and western Sabah have corals. Coral reefs are however limited in Sarawak where they are only found in the offshore islands northeast and southeast of Sarawak. Coral reefs in the Straits of Malacca show very poor development and are restricted to the northwest and southeast of the Peninsular. Coral diversity is relatively low here due to high turbidity and muddy substrates (Chua and Charles, 1980).

Figure 1 and 2 shows all the islands and islets (or rocks) that are located adjacent to the South China Sea where coral reefs can be found. Most of the islands within the States' coastal waters are within the marine parks. There are also many shoals and ocean reefs in the South China Sea that are rich in corals but are not protected.

BIODIVERSITY

Coral species

Surveys conducted on 64 percent of Malaysia's coral reefs since the 1980s show an overall live coral cover of between 25 and 50 percent (Ridzwan, 1994). Veron estimated that 70 genera of coral may be found in Malaysia (Veron, 1998). The UNEP World Atlas of Coral Reefs estimated that at least 346 species of scleractinian corals may be found in Malaysian waters (Spalding *et al.*, 2001). Data obtained in Malaysia shows the lists of 519 coral species that can be found in waters of Terengganu (Pulau Redang), Pahang (Pulau Tioman), Johor (Pulau Tinggi), Sabah (Taman Tunku Abdul Rahman, Turtle Island Park and Barvey Bay), Sarawak (Sibuti Reef and Miri Reef) and Pulau Layang Layang which were recorded between 1980 to 2000.

The acroporids are commonly found adjacent to most islands in Malaysian waters and are dominant along the east coast of Peninsular Malaysia. The coral species in the family Acroporidae consists of 71 species of genus Acropora, 3 species of genus Anacropora whereas massive coral species from the family Poritidae, Mussidae and Faviidae typically make-up coral reefs on the west coast of Peninsular Malaysia.

Associated marine biota

Estimates of number of coral reef fishes in Malaysia is 909 species (Allen, 2004). Pristine coral reefs may show a higher number of fish species. For example, research in the 1980s showed that coral fish diversity in a pristine area like Pulau Layang-Layang was higher than along Peninsular Malaysia. The number of coral reef fish species recorded in research conducted between 1980s-2000s are 210 at Redang, 219 at Tinggi, 355 at Taman Tunku Abdul Rahman, and 263 at Miri Reef (Wood, 1986; Allen, 1992; Department of Fisheries, 2003). Of all the coral reefs surveyed, Tunku Abdul Rahman Park showed the highest number of fish species.

Fish from the Chaetodonidae family are typically associated with coral reef environments. A comparative study conducted at Pulau Payar Marine Park and Pulau Singa located on the west coast of Peninsular Malaysia showed that the former had high numbers of Chaetodonidae (butterflyfish). It has been hypothesised that butterflyfish can be a bio-indicator for coral health (Reese, 1981). Hence, decreased numbers of butterflyfish could be caused by coral reef degradation (Sano *et al.*, 1987).

Of the nine giant clam species, seven from the genera *Tridacna* and *Hippopus*, exist in waters surrounding the islands of Malaysia. A total of four species have been observed on the east coast of Peninsular Malaysian, whilst seven species have been observed in Sabah (Tan and Zulfigar, 1995; Tan and Zulfigar, 1996; Tan *et al.*, 1998). Giant clams on the east coast Peninsular Malaysia, such as adjacent to the islands of Terengganu, Pahang and Johor, include the species of *T. squamosa*, *T. maxima*, *T. crocea* and *H. hippopus*. Sipadan Island has all seven species including *T. derasa*, *T. gigas*, and *H. porcellanus*. Despite giant clam being classified as an endangered marine species under the Fisheries (Control of Endangered Species of Fish) Regulations 1999 of the Fisheries Act 1985, giant clam populations face over-exploitation, particularly in Sabah.

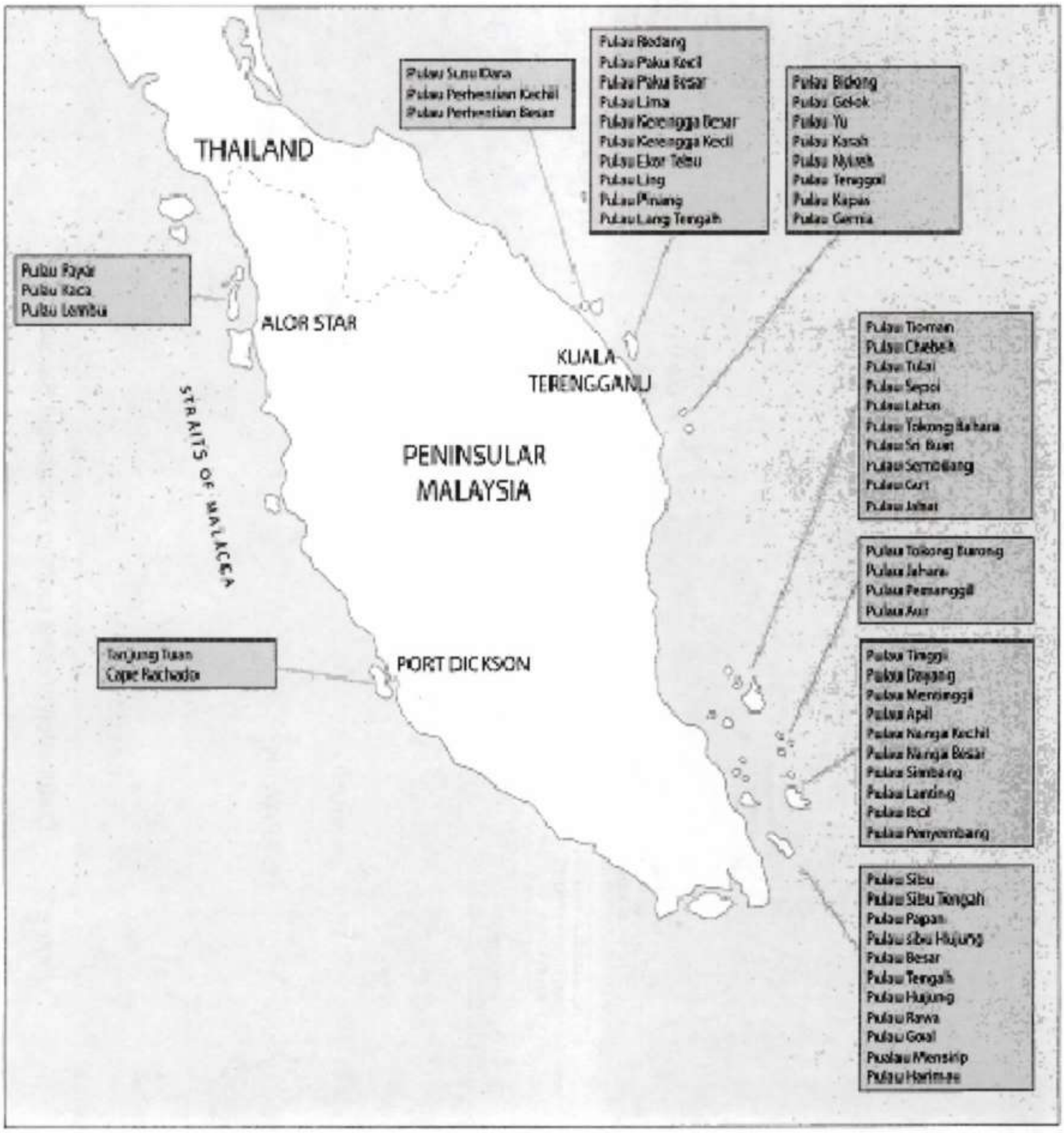


Figure 1 Distribution of coral reefs in Peninsular Malaysia.

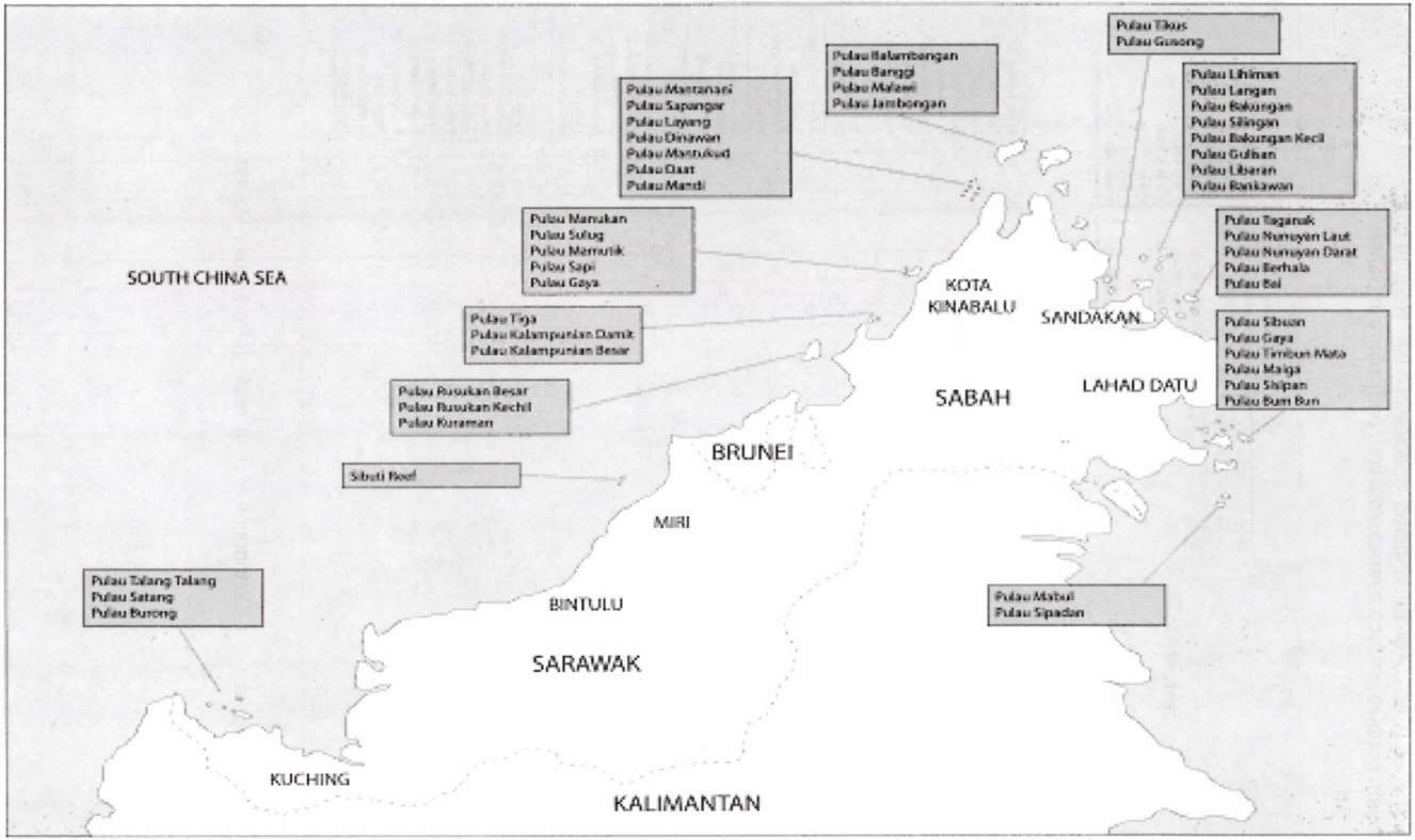


Figure 2 Distribution of coral reefs in Sabah and Sarawak.

Research on the distribution of other coral reef associated species is still incomplete in Malaysia. Therefore few publications exist, particularly relating to gorgonians, sponges, and nudibranchs. Hence, identification of non-coral species such as sponges is difficult due to the scarcity of taxonomic records (Zainuddin *et al.*, 2000) Intensive research has mainly focused on species of economic and pharmaceutical importance, such as sea cucumber. Many research projects have been carried out on sea cucumbers (Holothuridae and Stichopodidae) as they are used in traditional medicines. About 44 species of sea cucumber are recorded from coral reefs in Malaysia's marine parks (Forbes *et al.*, 1999).

In Malaysia, Sabah is the only state to have extensively harvested coral reef products, including coral reef fishes, sea cucumbers, and molluscs (Wood and Wood, 1978). Coral reef fish catches in Sabah made-up between 7.26 and 22.63 percent of total fisheries landings during the period of 1980 to 1990 (Cabanban and Biusing, 2000). Hong Kong is the main importer of live reef fish for food from Sabah. However, this is believed to be underestimated because of the underreporting of live reef fish capture (Lau and Parry-Jones, 1999). This happens because licensed fishing vessels and licensed live fish transporters in Hong Kong are exempted from declaring live reef food fish imports. Furthermore, the Hong Kong Marine Fish (Marketing) Ordinance (Chapter 291) does not categorise live fish as 'marine fish'.

Marine endangered species

No reliable data regarding the use of Malaysia's coral reefs by endangered marine mammal species exists. Available information is largely from anecdotal sources and occasional sightings made by researchers.

The Leatherback, Green, Hawksbill and Olive Ridley are the four turtle species that nest along Malaysia's coastal areas and islands (Figures 3 and 4). Of the four species, the hawksbill and green are associated with islands and reefs. The highest concentration of green turtles can be found in the islands of Pulau Redang, Pulau Perhentian, Sabah's Turtle Island and Talang-Satang National Park (Talang-Talang Besar, Talang-Talang Kechil and Satang Besar) (Ali *et al.*, 2004). There are also small numbers of green turtle nesting sites reported on the islands of Pulau Pinang, Pulau Telur (Kedah), and groups of islands in the Johor Marine Park consisting of Pulau Mertang, Pulau Lima, Pulau Pemanggil and Pulau Simbang (Mortimer, 1990).

Major hawksbill turtle nesting sites are located at Sabah Turtle Islands and Pulau Upeh (Malacca). In Sarawak, nesting sites were reported at Pulau Satang Besar (Bali, 1998). Although records of hawksbill turtle nesting on islands are occasional, this species has been observed to utilise waters of islands in West Johor and Terengganu (Liew, 2002). Islands and reefs are the key habitats for turtles to live and forage. Thus, turtles are regularly observed in coral reef areas around islands and coral reef associated ecosystem such as seagrass. There are also several records indicating that the Olive Ridley turtle utilise the islands of Sabah, Sarawak and Terengganu for nesting.

THREATS

Coral reefs throughout the world are facing unprecedented threats, particularly human induced threats. Despite their worth, coral reefs are continuously being impacted on by human activities such as pollution, coastal development, over-fishing, destructive fishing, and tourism related activities. Over 85% of the corals reefs in Malaysia are threatened and the type of threats facing Malaysian reefs differ by location (Burke *et al.*, 2002). Table 1 shows the type and scale of threats to coral reefs in Malaysia.

Sedimentation

Coastal development often results in the destruction of corals due to increased sedimentation or removal of coral reef substrate. Growing populations, expanding industrial economies, and emerging tourism markets are the key factors in the increasing demand for coastal space and the construction of infrastructure. The Reefs at Risk in Southeast Asia (RRSEA) project estimated that 23 percent of corals in Malaysia are affected by coastal development and sedimentation from upland sources. Coral reefs that have been affected by coastal development are more prevalent along the coast of Peninsular Malaysia, rather than in Sabah or Sarawak.

In East Malaysia, the reefs of Sarawak are at greater risk from sedimentation compared to those in Sabah. Some notable examples are the reefs near the Miri River and the reefs of the Talang-Talang Islands. According to the Miri-Suai Integrated Coastal Zone Executive Plan, sediments from the Miri and Baram rivers are threatening reefs that lie within 8-9 km of the mouth of these rivers. Sediments from the Lundu and Sematan rivers also affect the coral reefs of the Talang-Talang Islands (Pilcher and Cabanban, 2000). In Sabah, coral reef degradation due to increased sediment loads associated with land clearing, mangrove destruction, and reclamation can be seen in the Tunku Abdul Rahman Park.

Table 1 Threats to coral reefs in Malaysia.

Threats	West Coast of Peninsular Malaysia	East Coast of Peninsular Malaysia	East Malaysia
Fishing Intensity	4	3	5
Fishing Damage	3	3	5
Fish Blasting	2	2	4
Gleaning	2	1	3
Boat Scouring	2	3	4
Population Pressure	4	3	4
Sedimentation	5	3	3
Domestic and Agriculture Pollution	3	2	4
Industrial Pollution	3	1	1
Oil Spill	2	1	2
Disease and Predation	2	4	3
Dredging	2	1	2
Coral Mining	1	1	3
Tourist Activities	1	2	2
Coral Bleaching	1	1	1

The Scale Values: 1 = None to Rare; 2 = Very Low Concentration; 3 = Some Damage, Some Stress; 4 = Medium to High Damage; 5 = Very High, High Stress, Very Damaging.
Source: Malacca Straits Environmental Profile, 1997.

The World Resource Institute Report (Burke *et al.*, 2002) presented the percentage breakdown of reefs at risk in Malaysia ranging from low threat index (13% of total area), medium (44%), high (38%) to very high threat index (4%). The total area of reefs at medium or higher threats occupy 87% of the total coral reef area.

Visitor Pressure

Snorkelling is one of the most popular recreational activities among visitors to Malaysia's marine parks or coral reefs. Seventy percent of the survey respondents on Visitor Experiences and Perceived Conditions of Tioman Island Marine Park identified snorkelling as one of the activities that they usually engaged in while visiting the island (Ahmad, 2002). Snorkelling is an anthropogenic impact that threatens corals in the shallow waters as inexperienced snorkellers tend to either trample or stand on the reefs. Corals are also subject to damage by divers. Evidence of coral breakage in areas frequently used by SCUBA divers exists, but conclusive data or case studies for Malaysian coral reef sites that correlate the two are either scarce or unavailable.

Effluent Discharges

The issue of effluent discharges as a result of the introduction of tourism within the marine protected areas of Malaysia and further compounded by pollution discharge from households is indeed very common. Sewage, oil and grease, and grey water are among the long-standing pollution problems affecting the corals. A threat analysis study conducted at Redang, Tioman and Sibu-Tinggi islands showed that the three islands are affected by these problems. There are many cases of hotels, resorts and chalets discharging untreated sewage directly into the ocean. In Pulau Redang for example, the majority of small chalets on the island are using sub-standard sewage systems. The houses are also equipped with the same sub-standard facility in which concrete culverts are buried in the ground to hold the wastes. A water quality study of Pulau Redang coastal waters between 1995 and 2000 indicated some sewage contamination (Law *et al.*, 2001). The major source of contamination was from fishing settlements. The sewage treatment facility for Pulau Sibu-Tinggi in Johor and Tioman in Pahang is poorly developed and is inaccessible to most of the local population.

Accidental leakage of oil from passenger boats or ferries is another tourism issue that is affecting the health of corals in the marine parks of Malaysia. The problem is evident at the jetties and in areas where there is heavy boat traffic. There is also the problem of cooking oil and grey water being discharged directly into the river system from the adjacent business and residential premises. Sungai Lalang in Tioman is an example of river system being heavily polluted with these discharges.

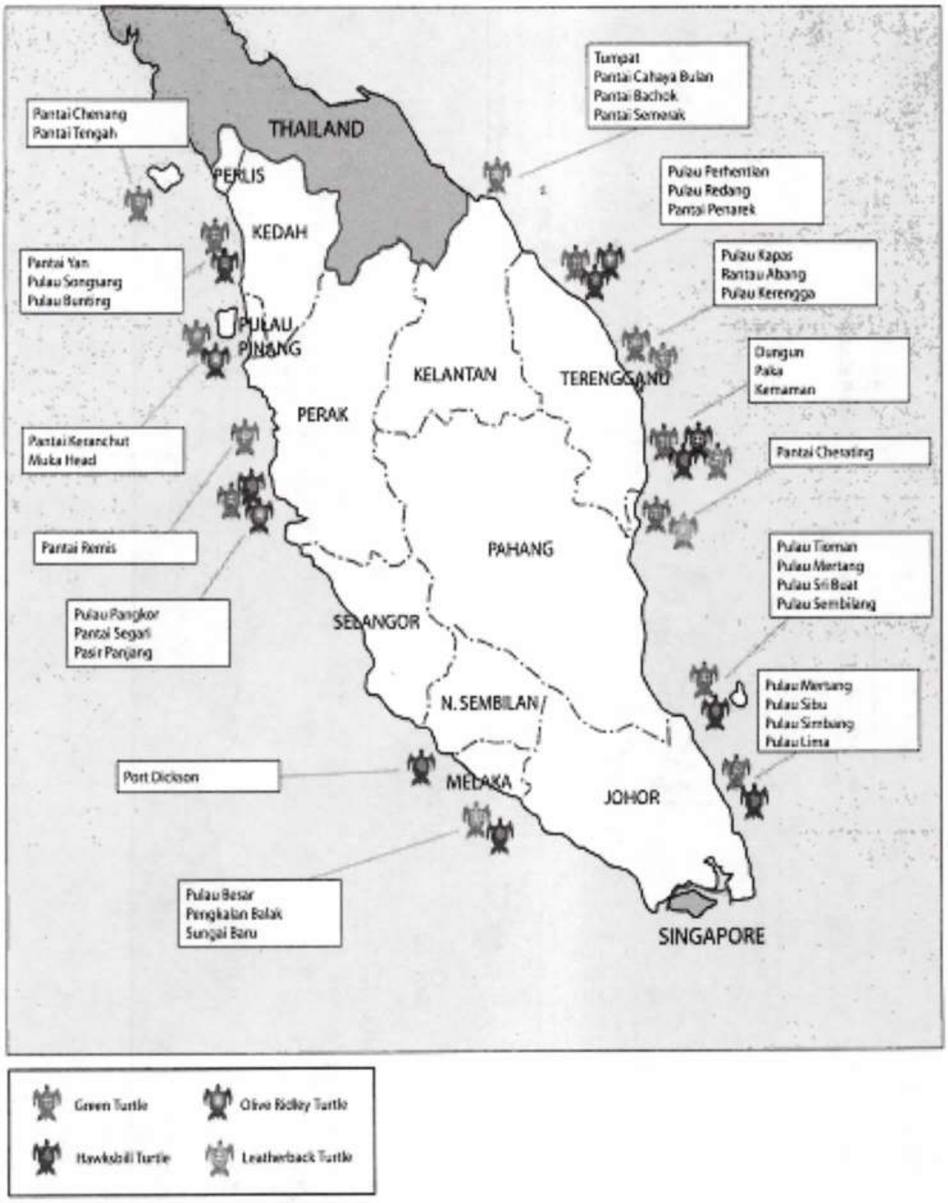


Figure 3 Distribution of turtle nesting sites in Peninsular Malaysia.

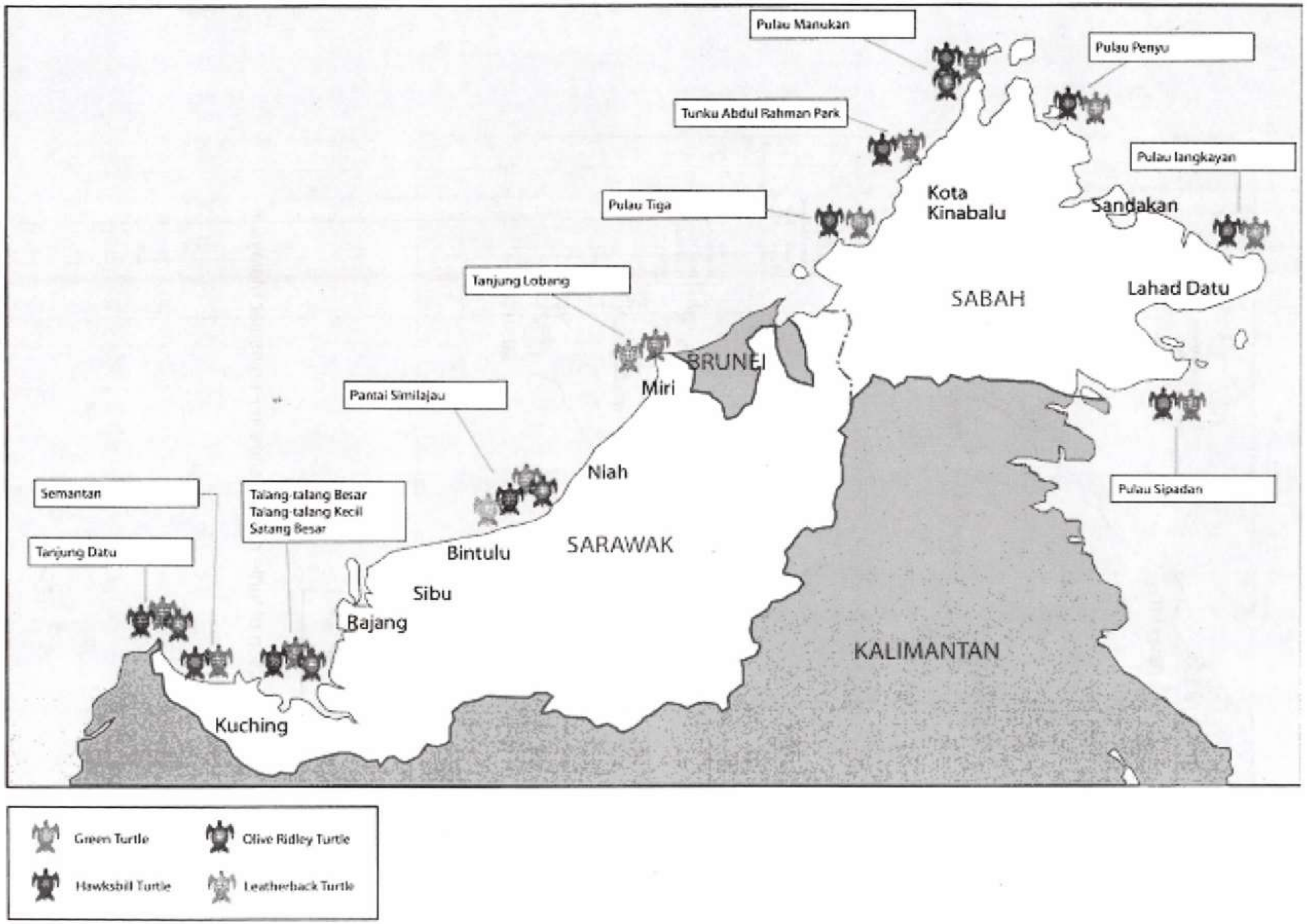


Figure 4 Distribution of turtle nesting sites in Sabah and Sarawak.

Destructive Fishing

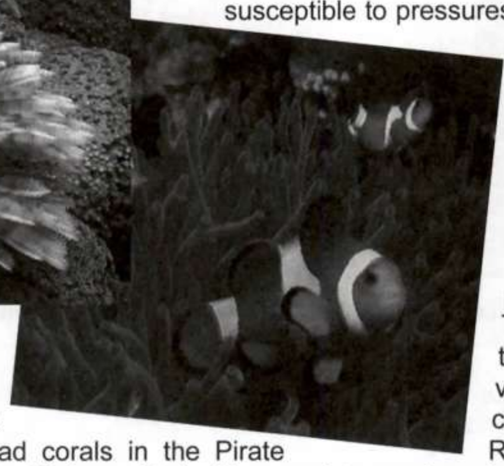
Corals reefs are also subjected to threats from destructive fishing techniques such as blast and poison fishing. The notable effects of these two fishing techniques are the destruction of corals reefs and the contribution towards overfishing of economically important fish and unintended exploitation of other species (Burke *et al.*, 2002). The problems of destructive fishing practices are more prevalent in East Malaysia, particularly in Sabah. The Reefs at Risk project estimated that blast and poison fishing is affecting 68 percent of Malaysian reefs. This estimate is based on data relating to the occurrences of dynamite and cyanide fishing, and the opinion of project experts.

Blast fishing is used to maximise catch and it usually occurs over or near coral reefs where fishes congregate. It is practiced along nearly the entire coast of Sabah, particularly at Labuan, which had resulted in the destruction of coral reefs and removal of various fish species. A thirteen-year (1980-1993) data set on coral fish landings from Sabah illustrated a drastic decline in the number of several important fish species (Figure 5). The decline is believed to be attributed to blast fishing (Figure 6) (Pilcher and Cabanban, 2000).

Cyanide fishing is used to catch high priced fishes like snappers, groupers and wrasses for the lucrative live fish trade industry. Cyanide fishing occurs at Kudat, extending out of Marudu Bay in the Northeast of Sabah to Banggi Island, as well as Labuan. In Kudat, there are several holding facilities to house the fishes awaiting trans-shipment. Humphead Wrasse, Barramundi Cod, and the coral groupers are sold for US$2.4 per kg to traders in Kota Kinabalu (Pilcher and Cabanban, 2000). The price soars 10 times higher for every kilo in the Singapore, Taiwan and Hong Kong markets.

SCENARIO

The closer the proximity of corals to human activity, the higher the likelihood of them being impacted on by human activities. Pressures can result in lower levels of biodiversity or at the extreme end – mortality. In April 2002, a resource survey was conducted at 12 locations in Pulau Tioman. At the best live coral sites, nearly 27% of dead corals were observed at Pirate Reef, 10% at Pulau Renggis, and 7.4% at Batu Malang. The three locations are close to human activities which make the corals within these areas more susceptible to pressures. Pirate Reef is located in the port area of Kampong Tekek which consists of two villages – Kg Tekek and Kg Air Batang. Kampong Tekek is known as the heart of Pulau Tioman. Among all the villages in Tioman, Kampong Tekek has the highest number of residents. In 2000, the total population of Kampong Tekek was recorded at 1,871. The community is heavily involved in tourism with 80% of the household heads engaged in it. Effluent from the villages, boats and tourism activities in the area could be contributing to the high percentage rate of dead corals in the Pirate Reef area. Pulau Renggis was ranked second and Batu Malang third with regard to coral mortality rates. Their close proximity to humans could be the reason for it. Pulau Renggis is located less than 1 km from a 5 star resort and it is frequented by tourists whereas Batu Malang is a popular dive and snorkelling site.



Note: 1. Feather duster worms on the shallow reefs of Tioman
2. Anemonefishes in Pulau Renggis
Photos Source: http://www.rossum.com/tioman00/tioman1.htm,
Underwater photographer: Dave Rossum

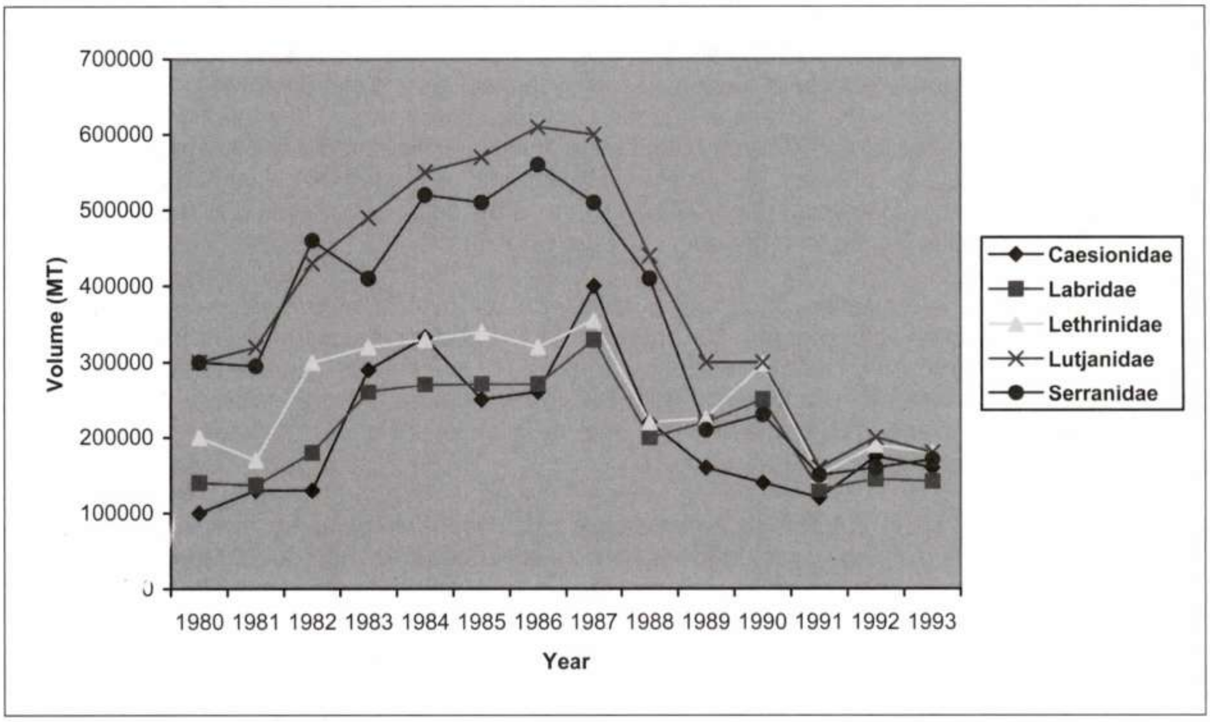


Figure 5 Landings of Coral Reef Fishes from Sabah Waters. (Cabanban and Biusing, in press)

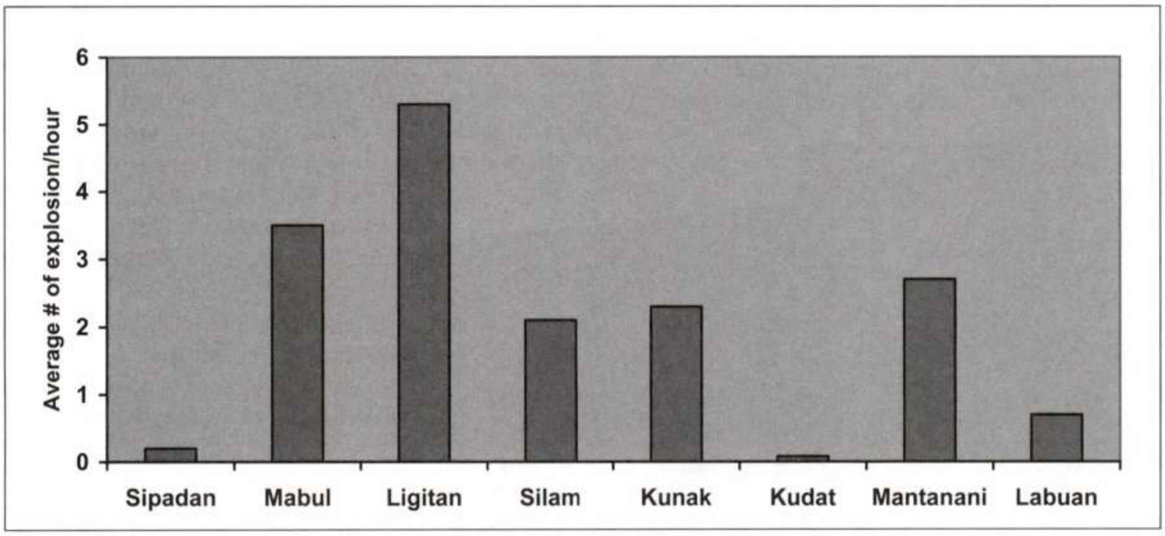


Figure 6 Average Blasts Per Hour Recorded at Various Coral Reef Sites Around Sabah. (adapted from Pilcher and Oakley, 1997)

SOCIO-ECONOMIC VALUATION

Corals reefs have significant socio-economic value. They are a vital source of food and income for coastal communities of Peninsular Malaysia and East Malaysia. Coral reefs are also effective in the prevention of shoreline erosion and the protection of mangrove and seagrass communities. They are also potentially valuable to the pharmaceutical industry for their biochemical properties. Coral reefs also contribute to the growth of the tourism industry. The coral reefs in the Malacca Straits have been valued at approximately US$563 million in terms of benefits associated with tourism, shoreline protection, fishery resources, and research potential (Burke and Spalding, 2002).

Tourism

Coral reef related tourism activities, particularly in protected areas, have gained popularity in tourism marketing and amongst visitors. The protection status of the distinctive and remarkably diverse coral reef ecosystems in Malaysia has set a platform for the tourism sector to develop. Aggressive tourism promotions of the natural assets of coral reefs have led to annual increases in the number of visitors to Malaysia's marine parks. Table 2 shows a high number of visitors to four coral reef sites in Malaysia from 1999-2002.

The economic importance of coral reefs to the tourism industry is indeed significant. Coral reefs are known to economically benefit more than 100 countries with their recreational values (Bryant *et al.*, 1998). In 2002, a report on the feasibility study of the Miri-Sibuti reefs had projected the potential revenue of diving activity for the reef area[4]. Assuming that 11, 984 divers on a 3 days/2 nights diving package will visit the Miri-Sibuti reefs by the year 2005, it is estimated that the potential tourism value for diving activity alone will generate a potential revenue of RM15,456,244.16 (Elcee Instrumentation Sdn. Bhd., 2002). Figure 7 shows the projection curve of divers visiting the Miri-Sibuti reef. The curve is projected based on the recorded figures from 1995-2001.

Table 2 Total number of tourists to Pulau Tioman, Pulau Payar, Turtle Islands Park, and Tunku Abdul Rahman Park 1999-2002.

Year	Pulau Tioman	Pulau Payar	Turtle Islands Park	Tunku Abdul Rahman Park
1999	184,954	83,203	8,732	171,919
2000	200,527	106,784	10,131	205,852
2001	243,052	125,485	8,250	198,576
2002	213,172	133,775	8,450	147,188

Sources: Department of Fisheries and Sabah Parks.

Capture Fisheries

Another aspect of the socio-economic importance of coral reefs relates to their critical role in the life-cycle of many economically important fish species. Corals are known to provide sheltering habitat essential for nursing and as a breeding ground for a variety of fish species. It is believed that approximately 40 percent of the commercial fish in Malaysia caught within the 30 nautical miles from the shore originate from or make use of the coral reefs (Phang, 1999). In 1999, for example, the coral reef capture fishery value for Miri was believed to be approximately RM40,080,684 (Elcee Instrumentation Sdn. Bhd., 2002). Miri also accounted for the largest volume of fish landings for the state of Sarawak in that year, 40 percent of which were economically important coral reef fish. In terms of the value of capture fisheries production, Sabah's coral reefs contributed to between 7.8% (RM3.3 million) of total value in 1992 to 11.5% (RM4.98 million) of total value in 1981 (Pilcher and Cabanban, 2000).

Socio-Economic Benefits

Recreational or tourism use of coral reefs will indirectly result in improved social conditions and commercial services in the given area. In January 2002, for instance, Pulau Tioman was accorded a duty-free island status; Malaysia's third duty-free island after Langkawi and Labuan. The Tioman Development Authority (TDA) had received approval to begin selected infrastructure projects such as the upgrading of roads and construction of a new airport. The infrastructure development in Tioman will be done in stages and will include the construction of low cost houses, retail space in Tekek (the island's main village), construction of a cargo jetty and several other road projects.

The ReefMap Report of Miri-Sibuti reef areas highlighted the likelihood of the villages gaining benefits if the reef area is promoted for eco-tourism. Among others are the infrastructure development, tourism amenities development, and enhancement of the hygiene system. The intangible benefits that would result from the promotion of the reef area as recreational or tourism destination are employment opportunities and/or employment security.

[4] *The report was prepared for the Sarawak State Government's consideration to gazette the Miri-Sibuti reef as a marine park and to promote eco-tourism in the area.*

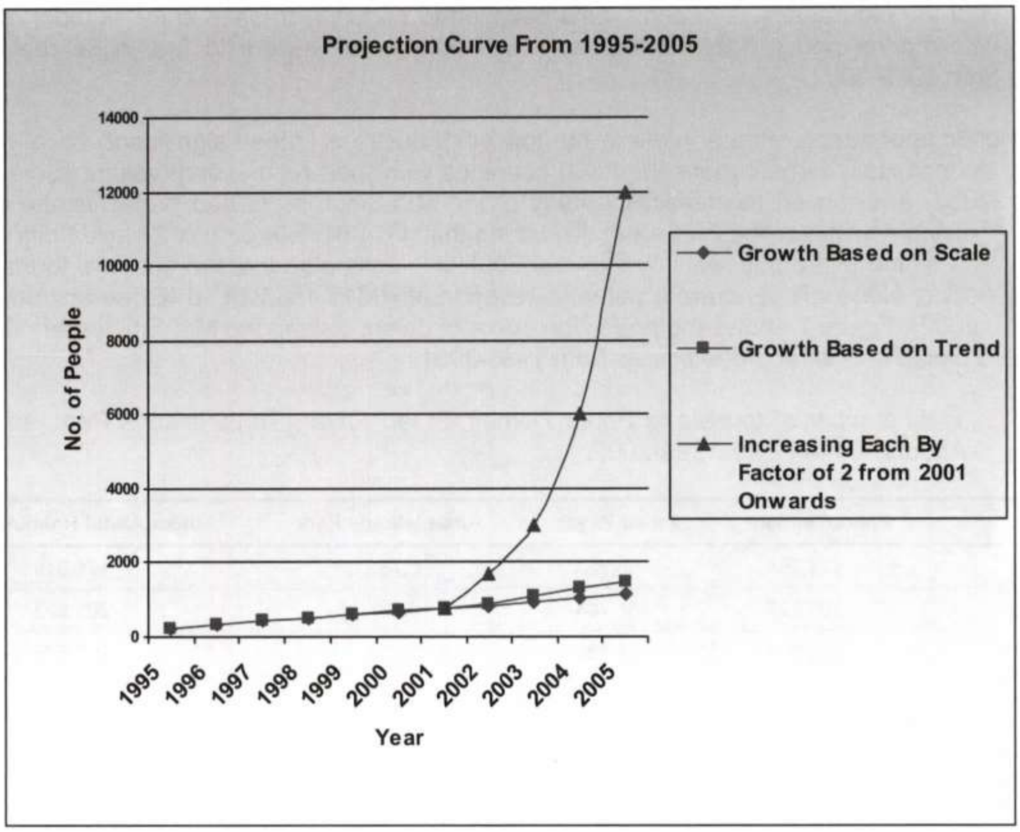


Figure 7 Projection Curve for Divers Visiting Miri-Sibuti Reefs.

MANAGEMENT

National initiatives to conserve coral reefs

In Malaysia, the protection, conservation and management of coral reefs and its associated fauna and flora is largely achieved through the establishment of marine protected areas (Marine Parks in Peninsular Malaysia and National Parks in Sabah and Sarawak). Malaysia has designated 136 marine protected areas (MPAs) including non-fishing areas, marine parks and marine reserves. Seven percent of these MPAs include by coral reef ecosystems (Ho, 2003). Malaysia established its first MPA in 1983 when Pulau Redang was declared the first MPA of Peninsular Malaysia under the Fisheries (Prohibited) Areas Regulations 1983. This regulation established a fisheries prohibited area in the 8km of maritime waters surrounding Pulau Redang. According to the Fisheries Act 1985, the Fisheries Department is the main government agency with direct responsibility for marine park management.

Another 21 islands were added to the list of fisheries prohibited areas under the regulation in the proceeding years. The Fisheries (Prohibited Areas) Regulations 1985 (Amendment), however, reduced the surrounding waters to 3 nautical miles (nm). The Fisheries (Prohibited Areas) 1988 (Amendment 1994) added three more islands off Sarawak (Pulau Talang Talang Besar, Pulau Talang Talang Kechil and Pulau Satang Besar) thus protecting a total of 25 islands. This regulation superseded the Fisheries (Prohibited Areas) Regulations 1983 which gazetted maritime waters within 8km off Pulau Redang. Since some fishing activities are destructive to coral reefs, all marine parks are protected from fishing activities. This regulation stated that, "No person shall collect shells, molluscs or corals within prohibited areas" and "No person shall kill or capture any fish within the fisheries prohibited area unless he holds a license issued under section 11 of the Act stating the respective location specified in column (1) of the Schedule as the fishing base."

Since 1998, 40 offshore islands have been gazzetted as Marine Parks under the Establishment of Marine Parks Malaysia (Amendment) Order 1998. These include some of the fisheries protected areas mentioned above. Table 5 shows the list of islands that are grouped into five Marine Parks:

1. Pulau Redang Marine Park in Terengganu;
2. Pulau Tioman Marine Park in Pahang;
3. Mersing Marine Park in Johor;
4. Pulau Payar Marine Park in Kedah; and
5. Labuan Marine Park in Federal Territory of Labuan.

The Fisheries (Establishment of Marine Parks Malaysia) Order 1994, further reduced the coverage of the marine park areas to 2km for all the marine parks except 1km for Pulau Kapas.

Sabah and Sarawak, which are autonomous in terms of managing their natural resources, have established their own MPAs and have State bodies for MPA management. The Sabah Parks Board of Trustees established under the National Parks Ordinance 1962 is responsible for the Sabah State Parks, including Marine Parks. The Board has been established directly under the Sabah's Ministry of Tourism, Environment, Science and Technology. Sabah Parks legally owns the marine parks and has mandate to control both the activities on the land area and in the water column. The Sabah Parks Board of Trustees also manages the collection of entrance fees to the Sabah Parks.

There are three State Parks in Sabah that have been established in the last 20 years, namely Turtle Island Park, Tuanku Abdul Rahman Park and Pulau Tiga Park. Pulau Tiga Park was gazetted in 1978 and is comprised of Pulau Tiga, Pulau Kalampunian Damit and Kalampunian Besar. The Pulau Tiga Park was established as a MPA because the area is comprises of a distinct mix of mud volcanoes, good coral reef, and sea snake nesting habitat on Pulau Kalampunian Damit (Wood and Wood, 1987). The Tunku Abdul Rahman Park located off Kota Kinabalu was established as an MPA in 1974 with the aim of conserving the diverse range of marine life at the site.

Several State agencies, namely the National Parks and Wildlife Office of the Sarawak Forestry Department, Sarawak Museum, and the Department of Fisheries manage marine ecosystems and their associated fauna and flora in Sarawak (Table 3). The National Parks and Wildlife Office is responsible for the implementation of the National Parks Ordinance (1956) and the Wildlife Protection Ordinance (1958, Amendment 1990), which conserve wildlife and their habitats including marine ecosystems. Since Pulau Talang-Talang Besar, Pulau Talang-Talang Kechil, and Pulau Satang are turtle nesting beaches, these islands are designated as turtle sanctuaries by the Turtle Board Trust and the Sarawak Museum. With this designation, the coral reef ecosystems of these islands are also protected.

Non-governmental organisations such as the World Wide Fund for Nature (WWF) Malaysia play an active role in the establishment of marine protected areas in Malaysia. For many years, WWF-Malaysia has been advising the Government to protect the vast maritime waters in the seas of northern Sabah, which borders the Sulu Sea in the East and the South China Sea in the South. In 2003, the Sabah State Cabinet endorsed the establishment of this area as the Tun Mustapha Marine Park. This will be the largest marine park in Asia, covering an area of 1,028,000 hectares and consisting of at least 50 islands off Kudat, Kota Marudu and Pitas districts.

The protection measures for some of the islands in Malaysia are not, however, specifically designed for the conservation of coral reefs. For example, despite its unique atoll reef of Pulau Sipadan, it is gazetted as the Sipadan Bird Sanctuary. Under this designation, coral reef and the maritime water of Pulau Sipadan are not provided any legal protection. To protect the marine ecosystem, Sabah's government is considering further management action and feels that the island should be listed as "World Heritage Area" under the United Nations Educational, Scientific and Cultural Organization (UNESCO) and as a "Particularly Sensitive Areas (PSSA)" under the International Maritime Organization (IMO). In April 2004, Government issued notices evicting dive resorts by the year end. Another possible listing as UNESCO's "world heritage area" for Sabah's reef is the Tun Mustapha Park.

Regional initiatives for coral reef conservation efforts

Regional co-operation in protecting transboundary coral reef areas can be achieved through the Large Marine Ecosystem (LME) concept. Malaysia is currently involved in two such initiatives namely, the Bay of Bengal Large Marine Ecosystem (BOBLME) and the Sulu-Sulawesi Marine Ecoregion (SSME). Malaysia is among the eight littoral countries in the Indian Ocean participating in the Bay of Bengal Program (BOBP). Under this program, studies on resource mapping (Lee, 2000) and carrying capacity assessment (Li, 1998) have been carried out in Pulau Payar.

Table 3 List of Islands Gazzeted as Marine Parks under the Establishment of Marine Parks Malaysia (Amendment) Order 1998.

	Name of Island	***State (Marine Parks)***
1.	Pulau Redang	Terengganu (Pulau Redang Marine Park)
2.	Pulau Perhentian Kecil	
3.	Pulau Perhentian Besar	
4.	Pulau Lang Tengah	
5.	Pulau Susu Dara	
6.	Pulau Lima	
7.	Pulau Ekor Tebu	
8.	Pulau Pinang	
9.	Pulau Nyireh	
10.	Pulau Tenggol	
11.	Pulau Kapas	
12.	Pulau Tioman	Pahang (Pulau Tioman Marine Park)
13.	Pulau Labas	
14.	Pulau Sepoi	
15.	Pulau Gut	
16.	Pulau Tokong Bahara	
17.	Pulau Chebeh	
18.	Pulau Sembilang	
19.	Pulau Seri Buat	Johor (Johor National Park)
20.	Pulau Rawa	
21.	Pulau Rawa	
22.	Pulau Hujung	
23.	Pulau Tengah	
24.	Pulau Besar	
25.	Pulau Tinggi	
26.	Pulau Aur	
27.	Pulau Pemanggil	
28.	Pulau Harimau	
29.	Pulau Goal	
30.	Pulau Mensirip	
31.	Pulau Sibu	
32.	Pulau Sibu Hujung	
33.	Pulau Mentinggi	
34.	Pulau Kaca	Kedah (Pulau Payar Marine Park)
35.	Pulau Lembu	
36.	Pulau Payar	
37.	Pulau Segantang	
38.	Pulau Kuraman	The Federal Territory of Labuan (Pulau Labuan Marine Park)
39.	Pulau Rusukan Besar	
40.	Pulau Rusukan Kechil	

The LME of Sulu-Sulawesi Sea lies between the South China Sea and the waters of the Indonesian archipelago. The initiative to conserve the SSME is to be undertaken by three countries, namely Malaysia, the Philippines, and Indonesia through the Conservation Plan of the SSME. The coral reef triangle of the SSME has been identified as a priority conservation area. The islands of Tun Mustapha Park are also located within the SSME.

Besides the LME concept, Malaysia is also involved in a Transborder Marine Protected Area initiative known as the Turtle Islands Heritage Protected Area (TIHPA). This transborder marine protected area was established by a Memorandum of Understanding between Malaysia and the Philippines in 1996 as a result of initiatives of the World Wide Fund for Nature (WWF). The Turtle Island Park in Sabah consists of Pulau Bakkungan Kechil, Pulau Gulisan and Pulau Selingan. The park was established in

1977 to protect the green turtle (*Chelonia mydas*) and the hawksbill turtle (*Eretmochelys imbricate*). The Turtle Island group has coral reefs at nine islands of the Sulu Sea. The Philippine islands consist of six islands, namely Boan, Langaan, Lihiman, Great Bakungan, Taganak, and Baguan.

Research for coral reef conservation

In support of coral reef management and conservation initiatives, research has also been undertaken on corals and coral reefs in the South China Sea region. These activities include:

I. Malaysia participated in the Living Coastal Resources (LCR) project under the ASEAN-Australia Economic Cooporative Programme on Marine Science. This ten-year project consisted of two phases. In Phase I (1984-1989), reef surveys and fish census was conducted at selected islands in Malaysia. During Phase II (1989-1994), the project was focused on monitoring the impact of tourism and development in Pulau Redang.

II. Collaborative surveys carried out by the Fisheries Department and WWF-Malaysia with financial support from Canada Fund Malaysia. This baseline data was used to prepare the Marine Park Island Management Conceptual Plan for Peninsular Malaysia (1994).

III. Through the United Nations Development Programme (UNDP), Global Environment Facility (GEF) funded field survey at Pulau Redang Marine Park, Pulau Tioman Marine Park and Pulau Tinggi Marine Park. The Malaysian government is planning to design a biodiversity conservation project on these marine parks.

IV. The David Emily Packcard Foundation for the status report of coral reef in Eastern Malaysia (2000).

V. With the support from World Resource Institute (WRI), the Town and Regional Planning Department (TRPD) in Sabah and the Borneo Marine Research Institute of the Universiti Malaysia Sabah carried out Reefs at Risk in Sabah. As part of the project outcome, coral reefs around the islands and along the shoreline of Sabah have been mapped and assessed for risks from threats, i.e. destructive fishing activities and sedimentation.

The above-mentioned surveys were aimed at providing information on the status, health and biodiversity of the Malaysian coral reefs, especially within the existing MPAs. The information is the basis for action to restore or to improve the existing management of the ecosystem. Decision making on the establishment of new MPAs is also supported by outcomes of research. For example, the decision of the Sarawak government to gazette the Miri-Sibuti reef as a state National Park was supported by a study on a profile of the reef through reef mapping exercises (ReefMap) and biodiversity assessments (Sarawak State Planning Unit, 2002).

More research on coral reefs will add to the knowledge-base of this important resource and assist in its protection. For example, the Scientific Expedition to the Seas of Malaysia (SESMA) of the University of Malaya's Maritime Research Center (UMMReC) has revealed that Pulau Perak off Kedah's coast is worthy of protection as an MPA, partly because of its unique island wall reef. However, the state government of Kedah would like to convert the island into a fishing paradise. In early 2004, there was also a proposal to partially protect Pulau Sembilan's coral reef in Perak's water from fishing activities. The Fisheries Research Institute of Malaysia carried out a study on the biodiversity of the island in support of the proposal but the decision on the gazettement of the reefs as MPA is still pending. It is worthwhile to note that Pulau Sembilan is considered as a rich fishing ground for Perak fishermen.

Pulau Layang-Layang, located off Labuan and within the Continental Shelf and Exclusive Economic Zone of Malaysia is not categorized as an MPA. However, the status of the island as a restricted area accords the reefs around Layang-Layang a high degree of protection. Research on baseline data of reef fauna and flora was carried out in within 20 nautical miles of the island has been carried out from the1980s until 2000. In 2003, the Department of Fisheries with cooperation from the Implementation Coordination Unit of the Prime Minister's Department (ICU, JPM) built the Marine Research Station Pulau Layang Layang (MARSAL). Short research expeditions to collect baseline information of its reef fauna and flora have been carried out in Pulau Layang Layang. Coral mining in the island for the construction of a seawall and an air strip, however has caused adverse impact on the coral reef. In the affected areas, live coral reef has reduced to 9.5% as compared to 30.9% in 1998 (Mohamed and Abdullah, 2004).

Many efforts have been made to restore and rehabilitate the corals, which include the artificial reef projects, coral transplantation and coral culture. Malaysian Universities, the Fisheries Research Institute and corporate bodies are involved in coral protection and propagation work. Such coral transplanting projects have been carried out in Pulau Perhentian and Pulau Tioman in 1999 and 2001, respectively. The internationally known Reefball project is another example of coral propagation using artificial reefs. This artificial reef was deployed in Pulau Talang-Talang off Sarawak. In 2004, with the help from the Department of Fisheries of Sarawak, PETRONAS, Shell and Sarawak Tourism Board, the Sarawak government has expanded its conservation effort through the "Rigs to Reef" project. Abandoned oil rigs in surrounding waters of Baram were relocated to Siwa. Here the rigs are transformed into artificial reef (Figure 8). Although this is a first in Malaysia, the project is not new because it has taken place in the Gulf of Mexico and Brunei since 1980s.

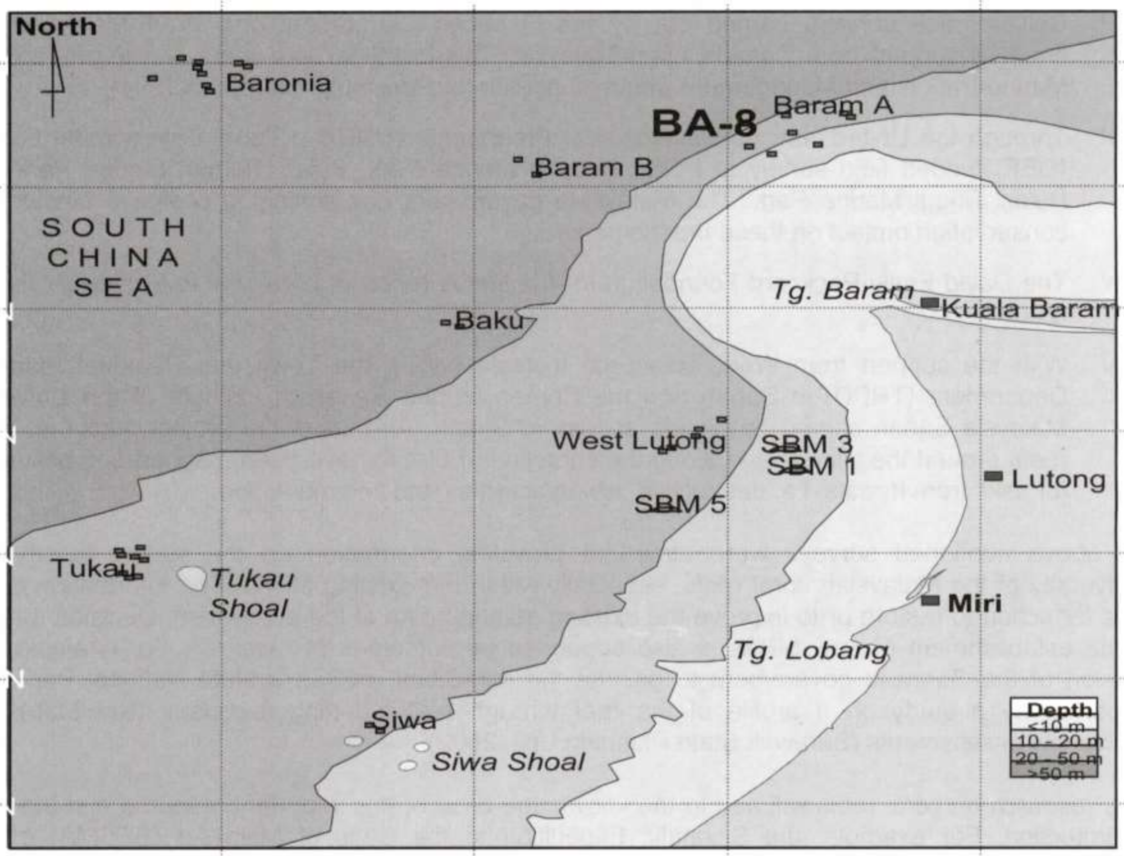


Figure 8 Artificial reefs of the "Rigs to Reef" Project. (Source: Department of Fisheries of Sarawak)

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NATIONAL REPORT
on

Coral Reefs in the Coastal Waters of the South China Sea

PHILIPPINES

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INTRODUCTION

The South China Sea (SCS) is one of the six major marine biogeographic regions in the Philippines (Figure 1). The western part of the Luzon Islands facing the South China Sea biogeographic region are composed of the Batanes province, and the Babuyan Islands, Cagayan province as the northernmost portion of this region. Ilocos Norte, Ilocos Sur, La Union, Pangasinan, Zambales, Bataan, Cavite, Batangas, Mindoro Oriental and Occidental, form the midwestern sector of the region in Luzon. The island province of Palawan composes the southwestern-most sector of the Philippine's section of the South China Sea.

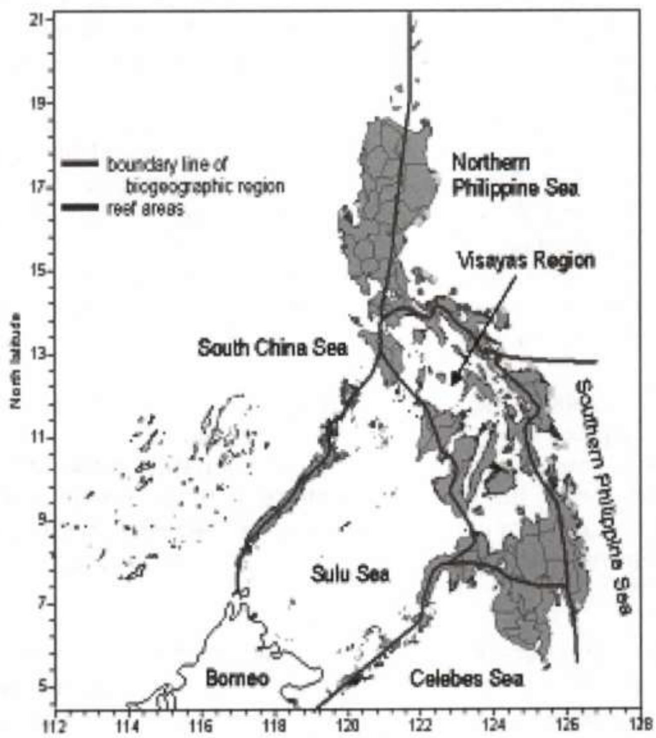

Figure 1 South China Sea (SCS) as one of the six major marine biogeographic regions in the Philippines. (Nañola *et al.*, 2004)

In the more recent past, the terrestrial and social conditions in Palawan have been referred to as one of the last frontiers - mainly in relation to the extent of the forest and marine ecosystems and high degree conservation consciousness of its stakeholders. The rich marine ecosystems of Palawan, especially coral reefs, are facing numerous threats from human activities. This appears to be a great obstacle to protection and conservation challenges. It is no surprise therefore that the Philippine reefs especially its South China Sea sector has been identified as one of the hottest of the hotspots in the marine realm (Roberts *et al.*, 2002).

The coral reefs in this marine biogeographic region compose approximately one-fourth of the total area of the coral reefs in the country. Municipal coral reef fisheries contribute to around 10-20% of the total municipal fisheries production in the Philippines (Murdy and Ferraris 1980). The provinces of Palawan, Mindoro (Oriental and Occidental), and Batangas, contribute the largest coastal tourism revenues associated with coral reefs. Important priority marine biodiversity areas are exemplified by at least three major marine corridors: the Batanes-Babuyan marine corridor which straddles the South China Sea and the North Philippine Pacific Seaboard; the Batangas-Mindoro-Palawan marine corridor straddles the South China Sea, Sulu Sea and Visayan Seas; and the Balabac Strait marine corridor in Southern Palawan situated in the southern transition of the South China Sea and the Sulu Sea.

As with the rest of the country, overfishing and siltation are the most predominant threats (Gomez *et al.*, 1994a, 1994b). Concerns related to population pressures have also been highlighted and may lead to food security deficits in the next decade (Bernascek, 1996; ArcDev, 2004). Some reefs experience marine coastal development concerns such as offshore oil drilling, port development and tourism establishments.

PHYSICAL FEATURES

The South China Sea marine biogeographic region experiences mixed tidal regime, wherein the northwestern Luzon sector primarily experiences a diurnal tidal regime with the rest of the other sectors having mixed – mainly diurnal tides. This is primarily influenced by the major currents that spill over from the major Pacific region.

The geological development of the Luzon archipelago circumscribes the marine biogeographic realm which straddles the: 1) the Northern Philippine Sea (NPS) portion of the Pacific Seaboard; 2) the Western Side of the Luzon Archipelago is referred to as the South China Sea (SCS); and 3) the Southern Luzon Area facing the Visayan Seas (e.g., in the Burias and Ticao Pass and San Bernardino Strait). Past geotectonic movement of the Luzon archipelago into the Northern/Western Pacific Ocean and the subsequent coalescence of the Visayan islands in the south and the Palawan archipelago have influenced the circulation of the adjoining seas (Hall, 2002). On the Eastern Side, the northerly movement of the Kuroshio currents bifurcates westward hitting the Batanes-Babuyan Islands Marine Corridor (Wyrtki 1961). This western movement into the SCS forms a northern gyre movement with a west to east flow (from Viet Nam to the Western Philippines) affecting the connectivity of the marine populations of this region (Shaw and Chao, 1994). The sill overflow in the Mindoro Strait affects the Sulu Sea region and the seas facing the Southern Luzon archipelago. The bays and gulf of the Luzon archipelago have been formed by geological faults influencing the extent of the coastal shelf and bathymetric slope inclination.

The coastal and marine habitats of the Palawan archipelago have undergone an extensive range of evolutionary and ecological processes. Palawan's incursion into the southwestern sector of the Luzon archipelago about 3 million years ago produced wedged sill between the SCS and Sulu Sea basins (Hall. 2002). The development of the coastal habitats (e.g., fringing reefs and mangroves) is greatly influenced by the geologic process of plate tectonics and sea level rise producing extensive shelves – adjacent deep basins (having oceanic atolls in the Kalayaan Islands Group (KIG) and Tubbataha Reefs).

On a broad-scale, western Philippine reefs are greatly influenced by the predominant current patterns and hydrodynamic regimes of the South China Sea. However, there are areas where reefs are constantly exposed to the exchange of water masses via the straits. For example, the Luzon Strait links the South China Sea and the Pacific Ocean while the Mindoro, Linapacan and Balabac Straits are major corridors for the exchange of water masses between the South China Sea and the Sulu Sea as well as to other adjacent seas (e.g., Sibuyan Sea in Romblon province).

CORAL REEF DISTRIBUTION

The coral reefs west of the Philippines, based on geographic location, can be categorised into two types namely: nearshore fringing reefs lining the coastlines of the islands and the more developed and extensive offshore reef areas like those in the Kalayaan Islands Group. The distribution of reef areas in this area is far ranging. With Manila as the reference point, reefs can be found far north such as the Batanes group of islands and along the western coastlines of Luzon Island (including the Scarborough shoal). Towards the south, reef areas fringe the bays of Batangas and Mindoro provinces. Apo reef, the second largest marine park in the country is situated along the Mindoro Strait. Southwest of Manila, reef areas can also be found in the Calamianes Group of Islands, along the main island of Palawan, and all the way to the Balabac islands. However, the most extensive and least explored reef areas can be found west of Palawan – the Kalayaan Islands Group (Figure 2).

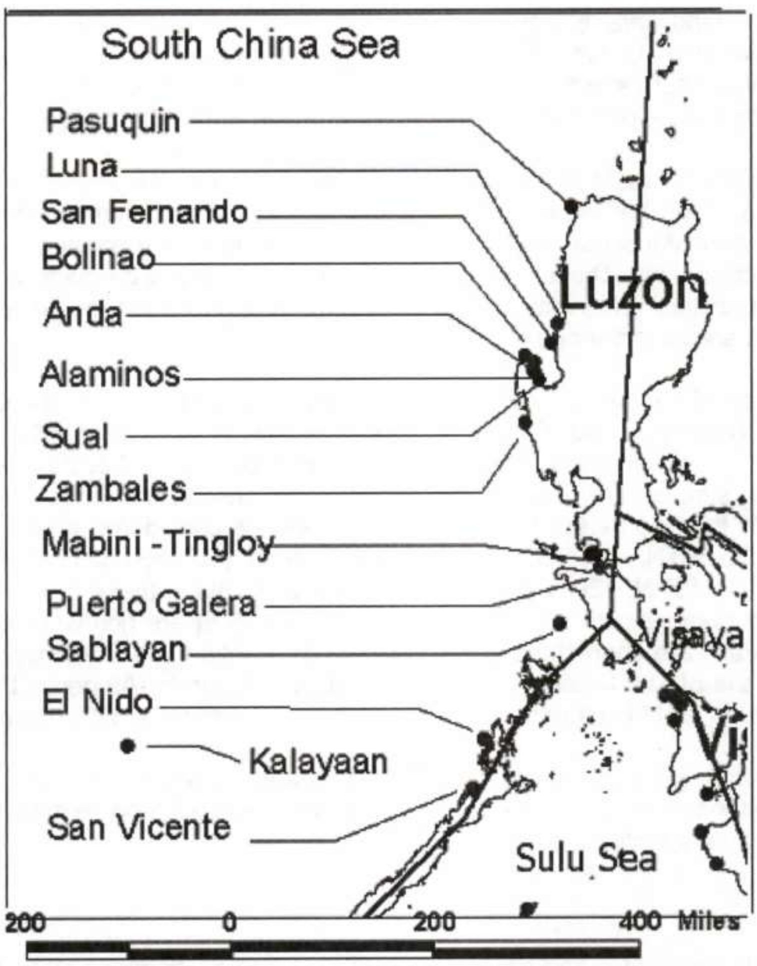

Figure 2 Coral reefs sites in the South China Sea biogeographic region of the Philippines.

Most of the largest extent of the reefs is found in the northern Palawan region. Some offshore ocean reefs are situated in the Kalayaan Islands and the Scarborough Shoals, Zambales. Many of the embayed areas that have headland areas having more extensive reef development and reef community structure are influenced by the embayment principle (Licuanan and Gomez, 1988; Hilomen and Gomez, 1988). Nañola *et al.* (2004) provides the most recent update on the state and conditions of the coral reefs of the country and shows that the SCS is second to the Sulu Sea area where over 30% of the coral reef areas remain at the highest level of fish biomass. Unfortunately, the SCS also shows one of the areas with the lowest fish abundance in the country especially that of Lingayen Gulf (Deocadez *et al.*, 2003, Nañola *et al.*, 2004). The offshore reefs in the Kalayaan Islands show the contrasting pattern and high variability in the condition of the diversity and state of its resources (Aliño and Quibilan, 2003). Here, the most extensive reef areas can be found with high species richness but also exhibit low abundance and impoverished reef conditions.

Characteristics of relevant coral reef sites

Davila is a coral reef site in the municipality of **Pasuquin** in the province of Ilocos Norte. The coral reefs are of the fringing type. The bay has low coral cover in the relatively exposed transect sites and good coral cover in the bay area. Its total coral reef area is 164.64 hectares and mostly dominated by *Acropora*.

Lingayen Gulf (including **Bolinao, Anda, Alaminos**) is located in northwestern Philippines. It is a large embayment (2,100km^2) surrounded by 15 municipalities and 3 cities, in the provinces of Pangasinan and La Union. The Gulf has been classified into three sectors according to dominant coastal features (Talaue-McManus and Chua, 1998). The western section (Sector I) is dominated by fringing coral reefs. The southern section (Sector II) is mainly soft bottom areas where majority of the river systems of the Gulf drain off. The eastern section (Sector III) is lined mainly by sandy beaches with patchy coral reefs (i.e., fringing and shoal) on the northern portion.

San Salvador is an island *barangay* (village) under the jurisdiction of the municipality of Masinloc, **Zambales**, in northwestern Luzon. The reefs in the northeastern part of the island are fringing, characterized by a vast reef flat with sudden drop-offs in the crest. Spur and groove formations are common along the reef crest, particularly in the area facing the South China Sea.

The diverse and abundant reefs in the **Mabini – Tingloy** area in the Province of Batangas, and Balayan Bay are known for their wealth of marine life. Bordering the Calumpan Peninsula containing Mabini municipality and Maricaban and Caban Islands of Tingloy municipality are many excellent fringing and patchy coral reefs. These reefs are famous for their natural productivity that supplies tons of fish to local communities. In addition, their color and diversity attract thousands of scuba divers and swimmers to the area every month of the year.

Puerto Galera is a small northern peninsula north of the island of Mindoro, with coordinates between 13° 23' and 13° 32' N latitude, 120° 50' and 121° 50' E longitude. It is acknowledged as one of the most highly diverse coastal areas in the Philippines (Campos, 2002). Coral reefs occur in shallow water, ranging from surface down to depths between 10 and 40m (Fortes 1997). Three sites monitored from 1991 to 1993 by the Phase II of the LCRP are considered in this report. These are First Plateau (13° 30.683'N, 120° 57.317'E), Third Plateau (13° 32.033'N, 120° 57.100'E), and Escarceo Point (13° 31.450'N, 120° 59.433'E). The coral reef flats in these areas appear to be poor although the sloping portions with depths ranging from 7 to 15 m are rich with reef-building corals. First and Third Plateaus are characterized by pocilloporids, poritids and *Seriatopora*, while Escarceo Pt. and the deeper site of Third Plateau are dominated by soft corals (Atrigenio 1995). Of the sites surveyed, Third Plateau had the highest mean percentage of live coral at 33% (Campos, 2002).

Port Barton Marine Park (**San Vincente**) is a 74,483ha marine reserve that stretches from the south shore of Albaguen Island to the rest of the inner bay. It includes reefs fringing many islands as well as patch reefs. Underwater visibility is generally very good.

BIODIVERSITY

The rich diversity of the South China Sea derives itself from its evolutionary history. It is situated in the Indo – West Pacific region where the coral reefs show the reefs at its zenith for both fish and coral species richness (Veron and Fenner, 2002; Carpenter and Springer, 2005). The eastern section of the South China Sea interphases with the Sulu Sea and Celebes Sea marine biogeographic regions (DeVantier *et al.*, 2004). Aliño (1994) and Aliño and Gomez (1994) discuss the significance of the Philippines' SCS in the overall global marine biodiversity conservation efforts. The Philippine National Biodiversity Priority Setting workshops further reinforce the importance of coral reefs vis-à-vis the other marine habitats and resources in the country. Below (Table 1) is a summary of the various characteristics of biodiversity in several sites of the SCS region and their relevant conservation and management responses.

Table 1 Summary of some of the noteworthy marine biodiversity features in the South China Sea and their conservation and management responses.

Sector or Area Cluster within the South China Sea region	Noteworthy Fauna	Responses
Northern Batanes - Babuyan Corridor	Humpback whales, turtles and manta rays approach the fringes of the reef areas	Protected Seascape and Landscape of the Batanes Islands and the Babuyan Islands are proposed priority protected areas through a marine corridor approach from NGOs like WWF and Conservation International
Northwestern Luzon (SCS)	Nesting areas are reported in the areas of Bataan and Zambales; the Scarborough Shoals together with the KIG show similarities in coral reef community fish composition that indicate the connectivity of these ecosystems	National Integrated Protected Areas System (NIPAS) sites such as Masinloc and Subic in Zambales are looking at complementary cooperation between local and national initiatives through Integrated Coastal Management and Watershed Approaches

Table 1*cont.* Summary of some of the noteworthy marine biodiversity features in the South China Sea and their conservation and management responses.

Sector or Area Cluster within the South China Sea region	Noteworthy Fauna	Responses
Batangas-Mindoro-Calamianes Marine Corridor	Dugongs and turtles foraging on seagrass and coral reef areas; coral reefs in this area show one of the highest diversity indices in this region	The Calamianes and Balabac marine corridors are part of the highest priority areas for marine biodiversity conservation through a marine corridor approach
Western Palawan	Irrawady dolphin, dugong and marine turtle nesting and feeding areas especially from Malampaya to Bacuit Bay and most of the coastline of the Western Palawan mainland; new species of corals such as *Leptoseris kalayaanensis* (Licuanan 2003) are being discovered in the adjacent oceanic atolls of the KIG	Many coral reef areas are being incorporated as part of the NIPAS system in addition to the Strategic Environmental Plan (SEP) of Palawan; noteworthy of these areas are Malampaya and El Nido which have considerable coral reef components
Balabac Marine Corridor	Aside from the presence of endangered species like the dugong and marine turtles, these areas are important migratory routes of commercially important reef associated fishes	A potential transboundary agreement can be forged between Sabah and Palawan for the conservation and cooperative research to sustainably manage the area – should be pursued

Aliño and Dantis (1999) summarises the insights derived from coral reef research as applied to marine biodiversity conservation in the following areas: 1) conservation biology in relation to marine protected areas; 2) resiliency to disturbances both from natural (e.g., storms and thermal anomalies) and human induced pressures (e.g., fishing pressure); and 3) recovery and susceptibility of different coral reefs vis-à-vis the other ecosystems as affected by various threats (e.g., siltation).

THREATS

Time series data on corals and reef fish in the South China Sea biogeographic region (PhilReefs 2005) show the trends for hard coral cover, reef fish abundance and biomass from 11 municipalities in seven provinces. Overall, hard coral cover for majority of the reefs (44%) are in stable condition while 39% are decreasing and only 17% are increasing. In terms of reef fish abundance, more than half (53%) are decreasing; whereas 27% are increasing and 20% are in stable condition or no net change. The same trend can be observed for fish biomass, where 45% are decreasing, 36% are increasing and 18% are in stable condition. However, it should be noted that not all municipalities or transect sites have a one on one correspondence of coral cover and fish abundance and biomass data in any year. As a result, totals for each category (i.e., hard coral cover, fish abundance and biomass) are not the same. Thus, percentages presented above are derived separately for each category and based only on available data.

Reef sites along the SCS biogeographic region were affected by the coral bleaching event in 1998 and are in various stages of recovery. Chronic disturbances such as siltation and overfishing are commonplace, and need to be addressed by local governments in all three provinces: Pangasinan, Zambales and Palawan. Illegal fishing activities (e.g., use of dynamite and fine-meshed nets) remain rampant in Pangasinan. There are reports of poaching inside MPAs like in Anda and Bugor Island, which are attributed to poor law enforcement activities (e.g., patrolling). This may also mean that there is a need to heighten local communities' environmental awareness as well as encourage active participation in coastal management efforts. Commercial fishers encroach in the municipal waters of Bani, Pangasinan, while coral reef fishes are excessively collected for the aquarium trade in San Salvador Island. In Port Barton, the establishment of seaweed farms seemed to have affected the water circulation within the bay. Natural disturbances such as the crown-of-thorns (COTS) outbreak that happened in May 2004 hampered reef recovery in El Nido. Abesamis (2003) demonstrates the differential vulnerability of offshore reefs to *pa-aling* (a more efficient substitute for *muro-ami*, Miclat *et al.*, 1991) in the Spratlys area vis-à-vis the marine corridor areas of the Calamianes and the Balabac areas. Perhaps this implies that despite the relative inaccessibility of the KIG areas they are quite vulnerable to commercial scale reef fisheries. Destructive and illegal fishing still remain the most prevalent threats as the result of what has been referred to as Malthusian overfishing (Pauly *et al.*, 1989; Alino *et al.*, 2004).

Threats at the site level

In **Nagabugan Bay, Davila**, coral bleaching has been observed. Blast fishing has stopped since the implementation of the Coastal Environmental Project (CEP) program. Sporadic cyanide fishing still occurs. Pollution is still a problem. Overfishing is not a problem in the area due to some established alternative livelihood projects like aquaculture, livestock raising and farming. Based on the 2000 survey, large areas with encrusting and massive corals were observed near the transect stations. However, deterioration on the condition of the corals sampled was observed. Possible reason for the decrease in live coral cover was the strong typhoons that hit Northern Luzon in the previous years that caused siltation in the area.

Overfishing, illegal fishing, siltation and pollution are the major issues and threats in the **Lingayen Gulf**. Capture fisheries with 23,000 fishermen exert very intense pressure in the Gulf. The number of fishers translates to about 7 fishers per meter of coastline or about 23 fishers per sq. km of municipal fishing ground. High fishing pressure is attributed to the steady increase of municipal fishers since 1976. Encroachment by commercial fishers (e.g., commercial trawl) is perceived as a major factor that caused the reduction in fishery production. Hence, small-scale capture fisheries has become the prevalent marginal occupation in the Gulf. The use of destructive fishing methods (e.g., dynamite, cyanide fishing and the use of fine mesh net fishing gear) has resulted in rapid habitat degradation and decline of the fishery stocks. Pollution in relation to mariculture activities (e.g., fishpens, fishcages and fishponds), and siltation from mine tailings, quarrying activities and erosion of agriculture lands have both affected water quality and productivity. Bolinao, at the western side of the gulf was adversely affected by the 1998 bleaching event (Arceo *et al.*, 2001).

Severe coral bleaching was observed in **San Salvador** in 1998. High exposure to storms is another natural threat to the reefs. Heavy siltation from river and agricultural run-off is also a major threat. Blast fishing is still occurring. Recently, aquarium fishers have gradually returned to fish in the reefs of San Salvador even though it is prohibited. In fact, several violators were observed while biophysical monitoring was going on. The extent of exploitation of aquarium fishes is a growing concern. Catch often includes juvenile fishes, and no limit in number or size has been set. Lastly, the presence of the National Power Corporation (NPC) coal power plant has always been of some concern due mainly to the increased seawater temperature brought about by the facility.

In **Maricaban Strait**, signs of destructive fishing activities are not as serious as in the past. Storm damaged corals in the late 1980s are being replaced with new developing corals although a storm in 2000 substantially overturned some coral heads at Sombrero, Arthur's and White Sand Reefs. Further, for the reefs to improve through increased coral growth, human-caused damage from anchors, fishing and careless scuba divers must be addressed. Tourism activity is high and increasing. The number of local boats used for diving and traveling by visitors has increased dramatically over the past ten years. Anchor damage is apparent on all the reefs except where the buoys are routinely used.

The total lack of solid waste management is very evident in the area. At every site, the survey encountered floating debris. Plastics are more common than jellyfish! Sediment deposited from heavy rainfall events was evident on the reefs bordering the Calumpan Peninsula especially at Twin Rocks and at White Sand Reef. This reflects deforestation and building constructions on land. The increasing construction activity along the shoreline is having negative impacts on the reefs in general. Most structures are constructed less than 20m from the high tide line as stipulated in the Land Management Act.

A major threat to the reefs in **Puerto Galera** is sedimentation associated with the development of coastal settlements, marble mining and goldpanning, and eutrophication brought about by sewage effluents from resorts and coastal settlements (Fortes, 1997). Water pollution may also have been brought about by discharges of watercrafts plying the area. The lack of enforcement of existing laws and ordinances as well as weak community participation in conservation efforts further aggravates the situation.

In **Port Barton**, the area still has good coral cover and much fish but it is having difficulty recovering from a storm that followed right after a mass bleaching event in 1998. Hard corals were devastated after a storm (Typhoon Norming) and this was followed by a mass bleaching event (April-May) in 1998. Hard coral cover percentage both inside and adjacent to the fishery reserve has since become generally stable but target fish species abundance (inside and adjacent to the reserve) appears to drop from 1999 to 2001. This decrease is also reflected in the major fish carnivores (groupers, snappers, emperors and sweetlips) and is more evident in adjacent areas compared to areas inside the reserve.

ECONOMIC VALUATION AND USES

Previous socio-economic resource valuation studies related to reefs in the Philippines

Past economic/resource valuation studies on coral reefs in the Philippines along the South China Sea basin has been done for provinces like Pangasinan, Palawan and Batangas. Studies have focused on these themes: socio-economic impacts of coral bleaching (Cesar *et al.*, 2001; Mamiit and Francisco, 2001), cost-benefit analyses of impacts of logging versus tourism and fisheries (Hogdson and Dixon 1988, 2000), economic valuation of biodiverisity (UPMSI-MERF 2002), determination of user fees (WWF-Philippines 2001, ENRAP-PAWB-PPSO, 1999), economic benefits of protection and small-scale tourism (White *et al.*, 2000a), and recreational benefits (Ahmed et al. unpublished). Other studies undertaken in the Philippines were in Olango, Cebu (White *et al.*, 2000b) and Apo Islands (Vogt, 1997).

There has been initial work on estimating the socio-economic impacts by coral bleaching in the Philippines. Most recent is the work by Cesar *et al.* (2001). In their study, the economic impact of coral bleaching to fisheries and tourism was determined for Bolinao, Pangasinan and El Nido, Palawan. A large percentage of corals bleached during the second half of 1998. Significant economic losses to tourism due to the coral bleaching event in El Nido was estimated at US$30 million (i.e., with the assumption that these losses were permanent at 9% discount rate). Losses to the fishery in Bolinao, Pangasinan, were more difficult to determine because of the confounding effect of overfishing and the nature of the fishery. There was, however, some indication of fish recruitment failure for rabbitfishes a year after the bleaching event. The study by Mamiit and Francisco (2001), determined that on the average around PhP3,756.67 (~US$70 @ PhP53: US$1), was the amount domestic (or local) recreational SCUBA divers were willing to pay for the restoration of bleached or damaged coral reefs in the Philippines. The contingent valuation method (CVM) was used.

Cost-benefit analyses on the impacts of siltation (i.e., derived from logging activities) on the fisheries and tourism in El Nido, Palawan (Hodgson and Dixon 1988) revealed that logging would severely limit the viability and income that would be generated from tourism and fishery. A follow-up study (Hogdson and Dixon 2000) showed that indeed tourism flourished after 10 years following the preservation of the unique forest ecosystem. However, there are now indications of increased fishing pressure that have resulted in overfishing. Populations of high-value species of fish and shellfish are significantly reduced.

An economic valuation was carried out for the period of 1986-1987. There were two options, i.e. (1) logging is banned; and (2) logging to continue. In Option 1, forest cutting was totally banned, tourism and fisheries kept on going, but there was one thing to be considered, i.e., compensation for logging owner. In Option 2, forest cutting continued, doubtlessly fisheries would keep on declining, so would be tourism. Results of calculation of the economic value of the three aspects (including Option 2-1) are given in Table 2.

An on-going project entitled "The economic value of coral reef biodiversity: Examples from Southeast Asia" aims to determine the estimated value of coral reefs specifically due to biodiversity. TOTAL FINA ELF Corporate Foundation funds this two-year project. This project is currently being implemented by the Marine Science Institute, University of the Philippines through the Marine Environment and Resources Foundation Inc. (MERF, Inc.) with collaborators from Viet Nam. Areas considered in this study are: Maricaban, Batangas, Hundred Islands, Pangasinan (both in the Philippines) and Hon Mun Island in Viet Nam.

Table 2 Tourism, fisheries and logging industries: ten-year sum of gross revenue and its present value (x $1,000) using 10% and 15% discount rates.

	Option 1	Option 2	Option 2-1
Gross Revenue			
Tourism	47,415	8,178	39,237
Fisheries	28,070	12,844	15,226
(with tuna)	46,070	21,471	24,599
Logging	0	12,884	-12,844
TOTAL	**75,485**	**33,906**	**41,579**
Present Value 10%			
Tourism	25,481	6,216	19,265
Fisheries	17,248	9,108	8,140
(with tuna)	28,308	15,125	13,183
Logging	0	9,769	-9,769
TOTAL	**47,729**	**25,093**	**17,636**
Present Value 15%			
Tourism	19,511	5,591	13,920
Fisheries	14,088	7,895	6,193
(with tuna)	28,308	13,083	10,039
Logging	0	8,639	-8.639
TOTAL	**32,599**	**22,125**	**11,474**

Source: *Hodgson and Dixon, 1988.*

Coral reef resource valuation from the UNEP SCS project

Samonte-Tan and Armedilla (2005) reviews the economic value (use and preservation values) of Philippine coral reefs in the South China Sea biogeographic region. The approach for estimating the economic value of coral reefs used the valuation framework agreed by the UNEP's Regional Task Force on valuation. The concept of total economic valuation highlights the significant economic values that can be accrued from use values and non-use values. Adding the above market (direct) and non-market values (indirect and option values) gives an estimate of the total quantifiable economic value of PhP2,901 million (US$53 million). Fisheries, tourism and research values account for about 27 percent of the total net economic value. Calculated over 20 years, with a discount rate of 10%, the net present value of benefits of Philippine coral reefs in the South China Sea basin is estimated at PhP24,700 million (US$449 million) that translates to approximately PhP5.3 million/km^2 net present value, or PhP 266,112/km^2/yr on an annualized basis. This is based on an estimated Philippine coral reef area within the South China Sea basin of 4,640.94km^2.

Samonte and Armedilla (2005) shows that 1km^2 of coral reef can generate US$11,366 direct and indirect values. Philippine coral reefs have an estimated value of PhP1,064 million/year (US$19.3 million) and the value of coral reefs for the South China Sea biogeographic region is estimated at PhP52.7 million/year as indicated in Table 3 (Samonte-Tan and Armedilla, 2005).

Table 3 Potential annual net economic benefit. (Samonte-Tan and Armedilla, 2005)

Resource Use (Direct and Indirect)	Philippines[a] ($ million)	Philippines-South China Sea Basin ($ million)
Fisheries	620.0	11.3
Tourism	108.0	2.3
Carbon Sequestration		8.4
Coastal Protection	326.0	23.2
Biodiversity	10.0	7.0
Research		0.7
Total Net Annual Benefits	1,064.0	52.7
Net Present Value[b]	9,063.0	449.1
Reef Area (km^2)	27,000.0	4,640.9

[a]*Burke et al., 2002.*

[b]*Stream of annual benefits over 20 years at 10% discount rate.*

Coral reef areas in the Philippines are major fishery resources and popular recreational attractions for domestic and foreign tourists. Current financing of coral reef management is insufficient considering the threats of land-based and marine-based human activities that cause irreversible damage to the coral reef resources. The results of Samonte-Tan and Armedilla (2005) study may help guide policy makers in evaluating/updating pricing policies (user fees, general tax revenues, fines, etc.) and in developing appropriate financing mechanisms.

MANAGEMENT

The specific national legislation, which updates the particular and fragmented marine related concerns are embodied in Republic Act 8550 known as the Philippine Fisheries Code. Previous to this (ca. 1991) more general laws such as the Local Government Code delineates the jurisdiction of municipal waters within 15 kilometers.

The significant decline of marine resources in the Philippines led various government institutions, provincial and local governments, non-government organizations (NGOs), people's organizations (POs), stakeholders and managers together with the local communities to spearhead the establishment of marine protected areas (MPAs), marine fishery reserves, sanctuaries and protected seascapes and landscapes. The coral reef and mangrove areas have been the primary focal areas where many of these targeted management efforts are directed. The management of these areas is regarded as the most appropriate approach in the management of fisheries because traditional fishery management efforts (e.g., regulating catch and fishing effort) are difficult to apply (Bohnsack, 1996; Arceo *et al.*, 2002). Marine protected areas also became popular with coastal managers because they offer simple win-win solutions. This approach is based on the assumption that an area closed to fishing will benefit adjacent areas through: 1) spillover of adult fish resulting from increased fish density; 2) export of larvae that could recruit elsewhere resulting from increased spawning stock; and 3) regulation of fishing effort if matched with the management of areas outside no-take areas.

Proliferation of marine reserves and sanctuaries in the late 1990s was due to the availability of funds from both foreign and local donors (i.e. International Grants, national and provincial governments). Other funding agencies supported efforts to sustain the management and protection of the marine biodiversity (e.g., Conservation International and the World Wide Fund for Nature). To date, more than 500 protected areas have been established in the Philippines (Aliño *et al.*, 2000, AFMA-MFR database, http://www.msi.upd.edu.ph/midas/). Majority of these MPAs were proclaimed under Presidential Proclamation No. 1801. Some MPAs are managed by the local government units (LGUs) together with the POs and local communities while others are managed by non-government organizations (NGO) with the support of LGUs, Bureau of Fisheries and Aquatic Resources (BFAR) regional offices, POs and the local communities. A number of MPAs were established under the National Integrated Protected Areas System (NIPAS) Act of 1992 and are being managed by the Protected Area Management Board (PAMB) in coordination with the Protected Areas and Wildlife Bureau (PAWB) of the Department of Environment and Natural Resources (DENR).

Protected areas that are managed by the community are sometimes considered to be very effective and exist continuously even with the change in local administration. However, these are successfully implemented in very small areas. Management efforts by local government (including coastal law enforcement) continue to rapidly gain ground, although its conservation effectiveness is not yet evident in the collected data.

Initiatives such as the Integrated Coastal Resources Management Project (ICRMP), Coastal Resources Management Project (CRMP), and Participatory Coastal Resource Appraisal (PCRA) were organized through partnerships between LGUs, NGOs and POs with the support of government institutions such as Department of Agriculture-Bureau of Fisheries and Aquatic Resources (DA-BFAR), Department of Science and Technology (DOST) and DENR. Other programs such as Fisheries Resources Management Program (FRMP) and Pacific Seaboard Research and Development Program were funded by the DA-BFAR and DOST, respectively, to assess and manage some of the priority areas for protection and conservation.

Sustainability of funds for the operation and maintenance of these protected areas is the most common problem in the Philippines. Many MPAs collect users fees from tourists (e.g., Apo Reserve and Tubbataha National Marine Park) that are kept as trust funds to sustain their operations. Resource use conflicts among local stakeholders, in addition to weak enforcement of ordinances and policies by the concerned agencies are the next most common problems (e.g., Visayan Seas region).

Based on submitted reports, from an initial list of 10 marine protected areas (MPAs) in 2003 (Philreefs 2003), five small MPAs, mostly from Pangasinan, and two proposed are now included. There are now 17 marine protected areas in the region, roughly covering a total area of 152,644ha. or 1,576km^2. Assuming that total coral reef area along the SCS biogeographic region is about 4,641km^2; the total area protected so far would be about 34%. This is an overestimate considering that not all marine protected areas are established on reef areas, some would include mangrove areas, seagrass beds or deep sandy areas.

Another source of information that was released recently is the MPA database 2004 by the Coastal Conservation and Education Foundation, Inc. (CCEF, Inc. 2004) (PhilReefs 2005). At present, there are 331 MPAs described in this database from all over the country. From this database, a total of 19 MPAs from the SCS was generated from it (Table 4). This list includes the large marine protected landscapes and seascapes, marine reserves and very small (i.e., ~2ha.) fish sanctuaries.

Management efforts, big and small, are continually geared towards setting aside areas for protection and conservation. However, it seems that despite these efforts, it may not be enough to save reefs on time. In the Philippine marine sanctuary strategy, the urgent call is to improve management effectiveness and sustain efforts within and outside marine protected areas (Aliño 2004). The sense of urgency stems from the fact that more than 50% of the reef areas monitored so far have shown decline in the reef condition (Philreefs 2003, Philreefs 2005), and that these areas are continually being exposed to varying degrees of exploitation and disturbances (human and natural). Greater challenges remain and questions need to be answered like: If we were to improve municipal fisheries by 10%, how many more MPAs do we need to establish? Do we increase the size of existing MPAs and by how much? How do we improve management effectiveness? How will we network these MPAs? What is the strategy or framework? Aliño et al. (2004) suggests that if a minimum of 20 hectares should be pursued in many of the existing areas, perhaps the projected 100-year period would be reduced by half (i.e. 50 years), and if, on the average, this will be increased to at least 40 hectares then perhaps it will reach a reasonable strategic period of 20 years.

Within the SCS bio-geographic region, only one MPA is declared a national marine park (i.e., Apo Reef Marine Reserve) while some are relatively small marine protected areas or fish sanctuaries (Table 4). Establishment of fish sanctuaries such as those in Bolinao and Anda, Pangasinan; Masinloc, Zambales; and Mabini-Tingloy, Batangas were made possible by passing municipal ordinances. However, the greatest challenge is how to manage reefs located in relatively larger areas such as Bacuit Bay, Lingayen Gulf and the Kalayaan Islands Group. Managing reef areas covered by more than one province and/or municipality or a number of barangays may be more difficult as it will need a more comprehensive management plan and regulations enforced by the various stakeholders in the area. How to manage offshore reefs in the Kalayaan Islands Group is a totally different story as it is claimed in part or whole by six countries. Based on ecological considerations, it is proposed that it be declared as the "Spratly Islands Marine Park" to benefit the whole region (McManus and Meñez 1997).

Table 4 List of marine protected areas/reserves and/or fish sanctuaries along the SCS biogeographic region generated from the MPA Database 2004 (PhilReefs 2005).

MPA/Fish sanctuary	Year of establishment	Size (ha)	Municipal ordinance (MO) and/or existing laws
Batanes Protected Landscape and Seascape	1994	213,578	Pres. Proc. No. 355 Feb 28 1994 Republic Act No. 8991-2001
Agoo-Damortis Protected Lndscape and Seascape Agoo, Sto. Tomas, La Union	2000	10,649	Pres. Proc. No. 277 23 April 2000 Republic Act No. 7160
Hundred Islands National Park Alaminos, Pangasinan	1940	1,630	
Masinloc Oyon Bay Marine Reserve, Masinloc, Zambales	1993	7,568	Pres. Proc. No. 231 18 August 1993
Nalayag Point Fishery Refuge and Sanctuary, Nalayag, San Agustin Kanluran, Isla Verde, Batangas City	2002	1	MO # 13 Series of 2002
Pulong Bato Fishery Refuge and Sanctuary, San Agapito, Isla Verde, Batangas City	2002	2	MO # 13 Series of 2002

Table 4 *cont.* List of marine protected areas/reserves and/or fish sanctuaries along the SCS biogeographic region generated from the MPA Database 2004 (PhilReefs 2005).

MPA/Fish sanctuary	Year of establishment	Size (ha)	Municipal ordinance (MO) and/or existing laws
Dive and Trek Fish Sanctuary San Pablo, Bauan, Batangas	1995	?	MO # 3 Series of 1995
Bagong Silang Marine Sanctuary Bagon Silang, Calatagan, Batangas	1999	5	MO # 92 Series of 2003
Carretunan Marine Sanctuary Caretulan, Calatagan, Batangas	2003	2	MO # 3 Series of 2003
Pagapas Bay Marine Reserve Tanagan and Sta. Ana, Calatagan Batangas	1998	2	
Sta. Ana Marine Sanctuary Sta. Ana, Calatagan, Batangas	1998	2	Resolution No. 89-1998
Tanagan Marine Sanctuary Tanagan, Calatagan Batangas	2002	2	
Brgy. Biga Marine Sanctuary Biga, Lobo, Batangas	2002	10	
Malabrigo Fish Refuge and Sanctuary, Malabrigo, Lobo, Batangas	2002	3	Resolution No. 60-2002
Sawang/Olo-olo Fish Sanctuary Sawang and Olo-olo, Lobo, Batangas	2001	9	MO # 59 Series of 2001
Batalang-Bato Fish Sanctuary Sto. Tomas and Talahib, Batangas	2002	2.5	MO # 1 Series of 2002
Malampaya Sound Protected Landscape and Seascape, Malampaya, Palawan	2000	200,115	Pres. Proc. No. 342, 11 July 2000
Manalo Fish Sancturay Manalo, Puerto Princesa, Palawan	2000	74	MO # 144 Series of 2000
Manyukos Island marine Sanctuary Buenavista, Puerto Princesa, Palawan	2003	232	MO # 246 Series of 2003 Part of St. Paul, Subterranean River National Park; IPRA Law
TOTAL AREA PROTECTED IN THE SCS BIOGEOGRAPHIC REGION		413,564	NOTE: The 193,255ha for Batanes was included in the computation.

In the Philippine Marine Sanctuary Strategy a proposal for a network of MPAs to be supported by a multisectoral body is espoused under the co-chair coordination of the Department of Agriculture – Bureau of Aquatic Resources (DA-BFAR) and the Department of Environment and Natural Resources (DENR). It has been proposed that beyond MPAs, an Archipelagic Development Strategy provides an overarching framework for all strategies within an ecosystem-based framework. ArcDev (2004) integrates the various habitat-based and project-based efforts into area-based – catchment "watershed" management approach linked to integrated coastal management. To date, no formal legitimised document provides this institutional framework. Existing legislative instruments should be utilised to incorporate improve implementing mechanisms for achieving targets of various action plans.

Though it has been legislated that municipal development plans should provide the basis for each local government's strategic action plans, only a handful (in the mid 1990s) has developed their coastal development plans with their appropriate zoning schemes. In the last 5 years coastal management plans have been initiated in an increasing number of LGUs found in the South China Sea region (e.g. in Batanes, Lingayen Gulf, Bataan, Batangas and Palawan). Budgetary allocations reaching at least around US$5,000 annually for coral reef management are often related to marine sanctuaries established in coral reefs. Perhaps due to the recognition of the gap in the co-ordination among local governments, which should function co-operatively, and share in the management of municipal waters, provincial and/or baywide management bodies have been established. The Strategic Environmental Plan legislated for the province of the Palawan (1992) and the National Integrated Protected Areas (NIPAS) declaration of Batanes as a Protected Seascape and Landscape are some of the provincial exemplary models for provincial initiatives engraved in national law. Other local provincial ordinances and executive issuances have been promulgated through the provincial governments as seen by the initiatives in Batangas and Bataan. On-going efforts among provinces to revive the baywide management arrangements (as espoused by the RA 8550) in Lingayen Gulf is being undertaken between the Provincial Governments of Pangasinan and La Union together with the support of other national government agencies like the DA-BFAR, DENR and the National Economic Development Authority (NEDA).

Despite the need for better inter-hierarchical coordination at the local and national levels, hope springs forth as seen in on-the-ground efforts, which have borne fruit in recognition of good practices in MPA management (e.g. Masinloc, Zambales winning the "Galing Pook" national award) and the CRM regional working group in Lingayen Gulf winning an award for its coastal zone management.

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GEF

Global Environment
Facility

NATIONAL REPORT
on

Coral Reefs in the Coastal Waters of the South China Sea

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INTRODUCTION

Thailand's coastal areas, located between 6?N and 13?N, offer suitable environmental conditions for coral reef development. The total coastline of Thailand, in the Andaman Sea and the Gulf of Thailand, is approximately 2,614 kilometres. The Gulf of Thailand, a major area in Southeast Asia, immediately to the west of the South China Sea is bordered by several nations, i.e., Viet Nam, Cambodia, Thailand and Malaysia. Thailand has historically profited from the wealth of living and mineral resources in the Gulf. Several millions of people derive their livelihoods from fisheries and mineral resources produced from the Gulf of Thailand, however, several millions more are affected by changes in the environment including coral reef habitat, whether these changes are physical or political. The Gulf of Thailand is a semi-enclosed sea, as defined by the Law of the Sea that measures approximately 400 km by 800 km, covering an area of about 320,000 square kilometres. The Chao Phraya, Tha Chin, Mae Klong, and Bang Pakong rivers enter the gulf. There are also many small rivers that flow along the coast. The Gulf of Thailand harbours a large area of coral reefs, seagrasses beds, and mangroves. Coral reefs represent an important part of the ecosystem that is in danger of becoming dangerously depleted. Coral reefs in the Gulf of Thailand are a home of many species of fish and other benthic organisms. These coral reefs are very sensitive to pollution, and are under threat from certain fishing and tourism activities.

PHYSICAL FEATURES

Climate

The majority of the Gulf coastline belonging to Thailand has a tropical climate dominated by the monsoons. The climate is characterised in general by four seasons: a dry season from January to February; a hot season from March to May; a wet season from June to October; and a cool season from November to December. Approximately 90 percent of rainfall occurs during the wet season. Annual precipitation varies from 1,000mm to 2,030mm depending on the region. In Bangkok, the average temperature ranges from 20?C in December to 35?C in April.

Geology

The Gulf of Thailand is part of the Sunda Shelf and is relatively shallow. The mean depth is 45m, and the maximum depth is 80m.

Hydrology

The Gulf of Thailand receives water mainly from the Chao Phraya, Tha Chin, Mae Klong and Bang Pakong rivers. Among these rivers, the Chao Phraya has the largest catchment area (162,000km^2), which is a one third of the whole area of Thailand.

An in-depth and systematic study of the oceanographic conditions of the Gulf was undertaken by the NAGA Expedition, which lasted from 1959-61, and was sponsored by Thailand, South Viet Nam and the United States of America. The results showed several physical properties of the Gulf of Thailand. The Gulf is a two layered, shallow-water estuary. The upper layer has low salinity due to rain and freshwater runoff from rivers. The deeper layer has high salinity due to cool water flowing into the Gulf from the South China Sea at the mouth. Monsoons, tidal currents and precipitation drive the Gulf's circulation and influence its salinity and turbidity. Monsoons also have a significant influence on the surface currents. During the southwest monsoon season, the surface current moves clockwise and during the northeast monsoon season it moves counterclockwise.

Water Quality

Water quality along the coastal areas and tourist beaches is mostly fair, except for some locations at the mouth of Thailand's four major rivers. Primary productivity in the Gulf of Thailand is boosted by increased nutrients from rivers, shrimp farms and household sewage. Many cities have no sewage treatment and discharge directly into the Gulf. More fertilisers are being used on agricultural lands. They eventually reach the Gulf and contribute to the deterioration of water quality. The increase in inputs of nitrate, phosphate and silicate are causing occasional algal blooms and oxygen depletion. Summary seawater temperature, salinity, dissolved oxygen and suspended solids data at coral reef sites in the Gulf of Thailand are given in Table 1, while concentrations of nutrient components in the coral reef sites are presented in Table 2.

Table 1 Important environmental factors at coral reef sites in the Gulf of Thailand.

Coral Reef Sites	Temperature (°C)		Salinity (ppt)		Dissolved oxygen (mg/L)		Suspended Solid (mg/L)	
	Wet season	Dry season	Wet season	Dry season	Wet season	Dry season	Wet season	Dry season
Chumphon Group, Chumphon Province	29-31	31-35	27-36	27-36	6-8	4-8	0-681	0-100
Koh Chang, Kud and Mark, Trat Province	27-31	31-33	9-27	27-36	6-10	6-8	50-681	50-150
Ang Thong Group, Surat Thani Province	27-31	29-33	27-36	27-36	6-87	4-8	0-100	0-100
Samui and Phangan Group, Surat Thani Province	29-31	29-35	27-36	27-36	6-8	4-8	0-50	0-100
Samet Group, Rayong Province	29-33	31-33	27-36	18-36	4-8	4-8	0-100	0-100
Sichang Group, Chonburi Province	29-31	29-33	18-36	18-27	4-8	6-8	50-861	0-50
Sattaheep and Samaesarn Group, Chonburi Province	29-31	31-33	27-36	27-36	4-8	6-8	0-50	0-50
Lan and Phai Group, Chonburi Province	29-31	29-33	18-36	27-36	2-8	2-8	0-400	0-100
Chao Lao, Chanthaburi Province	29-31	31-33	9-36	27-36	6-8	6-8	100-861	50-915
Prachaub Khiri Khan Group, Prachaub Khiri Khan Province	29-38	29-35	18-36	27-36	6-10	6-8	200-861	0-915
Tao Group, Surat Thani Province	29-31	31-33	27-36	27-36	6-8	6-8	0-50	0-50
Koh Nhu and Maew, Song Khla Province	29-31	31-33	27-36	27-36	6-8	6-8	0-100	0-100
Koh Kra, Nakorn, Srithamarat Province	29-31	31-33	27-36	8-27	4-6	4-6	0-50	0-100
Koh Losin, Narathiwat Province	29-31	29-31	27-36	27-36	6-8	6-8	0-50	0-50

Source: *Department of Pollution Control, 2004.*

Sedimentation

The average rate of sedimentation in the Gulf of Thailand during July to December was 2.004g/cm^2/mo, while that from December to June was 5.632g/cm^2/mo. The sedimentation rate in the deeper area during June to December was 3.036g/cm^2/mo and during December to June was 4.178g/cm^2/mo. In the northern part of Koh Sak island (Rayong Province), the rate of sedimentation in shallow and deep areas was low during both July to December and December to June. In general, the rate of sedimentation was higher in the shallow than in the deeper areas. Sedimentation was usually found highest at the southern part of the island, particularly during December to June, but lowest in the shallow water from July to December (Sudara *et al.*, 1992).

CORAL REEF DISTRIBUTION

The coral communities in the Gulf of Thailand could be categorised into three distinct areas with different oceanographic conditions (Figure 1), i.e., the inner part of the Gulf of Thailand (Chonburi), the east coast of the Gulf of Thailand (Rayong, Chanthaburi and Trad) and the west coast of the Gulf of Thailand (Prachuab Kirikhan, Chumporn, Surathani, Nakhon Si Thammarat, Songkhla, Pattani and Narathiwat).

Table 2 Major nutrient components in coral reef sites in the Gulf of Thailand.

Coral Reef Sites	Nitrate-Nitrogen (mg/L)		Nitrite-Nitrogen (mg/L)		Ammonia-Nitrogen (mg/L)		Phosphate-Phosphorus (mg/L)	
	Wet season	Dry season	Wet season	Wet season	Dry season	Dry season	Wet season	Dry season
Chumphon Group, Chumphon Province	0-200	0-100	0-25	0-50	0-50	0-25	0-600	0-200
Koh Chang, Kud and Mark, Trat Province	0-100	0-100	0-25	0-50	0-50	0-25	0-200	0-200
Ang Thong Group, Surat Thani Province	0-100	0-100	0-25	0-50	0-50	0-25	0-200	0-200
Samui and Phangan Group, Surat Thani Province	0-100	0-100	0-25	0-50	0-50	0-25	0-200	0-200
Samet Group, Rayong Province	0-100	0-100	0-25	0-50	0-50	0-25	0-200	0-400
Sichang Group, Chonburi Province	0-100	0-100	0-25	0-50	0-150	0-25	0-200	0-400
Sattaheep and Samaesarn Group, Chonburi Province	0-100	0-100	0-25	0-50	0-50	0-25	0-200	0-200
Lan and Phai Group, Chonburi Province	0-100	0-100	0-25	0-50	0-50	0-25	0-200	0-200
Chao Lao, Chanthaburi Province	0-100	0-100	0-25	0-50	0-50	0-25	0-200	0-200
Prachaub Khiri Khan Group, Prachaub Khiri Khan Province	0-100	0-100	0-25	0-50	0-50	0-25	0-200	0-200
Tao Group, Surat Thani Province	0-100	0-100	0-25	0-50	0-50	0-25	0-200	0-200
Koh Nhu and Maew, Song Khla Province	0-100	0-100	0-25	0-50	0-50	0-25	0-200	0-200
Koh Kra, Nakorn, Srithamarat Province	0-100	0-100	0-25	0-50	0-50	0-25	0-200	0-200
Koh Losin, Narathiwat Province	0-100	0-100	0-25	0-50	0-50	0-25	0-200	0-200

Source: *Department of Pollution Control, 2004.*

Three types of coral communities in the Gulf of Thailand are obviously recognised i.e., coral communities, developing fringing reefs and early formation of fringing reefs. Since there are four major rivers, which flow into the inner part of the Gulf of Thailand, most of these coastal areas are dominated by mangrove forests. However, scleractinian coral communities can be found around several islands in the inner part of the Gulf Thailand. The most inner islands, Koh Sichang, have a unique type of coral community. Eighty-five species of hermatypic corals were found (Sakai *et al.*, 1986). *Porites lutea* is the most abundant species and grows on the widest vertical range. Other abundant species are *Montipora hispida*, *Acropora formosa*, *Pavona frondifera*, *Platygyra daedalea* and *Pseudosiderastrea tayamai*. Sediment is considered as a significant factor, among others, that inhibits coral growth. After Koh Sichang, there is the Pattaya group, which consists of several islands. The coral reefs around the islands in South of Pataya have been used for tourism and the area of Sattaheep is controlled by the Navy. The coral communities are in relatively good condition (Chou *et al.,* 1991). On certain islands within this area, turtle conservation and coral rehabilitation projects have been undertaken.

In waters of the eastern Gulf of Thailand, coral communities around small islands in Rayong Province once had very good live coral cover, but due to illegal dynamite fishing and increased tourism, the coral communities of several islands have now deteriorated. Farther along the east coast to Chanthaburi, most of the coastal areas are mangroves. However, coral reefs are found in patchy distribution along the shore where there is no river runoff and around a few small islands. There are many islands with coral reefs in Trat Province. The coral reefs in this area are well developed and in very good condition before the coral bleaching phenomenon in 1998.

In waters of the western Gulf of Thailand, a few small islands exit with newly formed fringing reefs in Prachuab Kirikhan. The branching growth form of *Acropora* spp. was the most dominant species before the severe coral bleaching in 1998. In Chumphon Province, coral reefs are best developed on the eastern side of islands. Fresh water and sediment from land inhibit reef growth on the western sides of these islands. There are many islands with corals in good condition. Farther south to Surathani, there are several islands which harbor well developed coral reefs. Koh Samui, Koh Pha-Ngan and Koh Tao Islands are popular coral reef tourism destinations (Chankong, 2000).

A comprehensive reef survey programme was conducted between 1995 and 1998 at 251 sites in the Gulf of Thailand and 169 sites in the Andaman Sea (Department of Fisheries, 2000). The condition of reefs in the Gulf of Thailand was: 16.4% excellent, 29% good, 30.8% fair, and 23.8% poor. However, the figure of poor condition was considerably increasing after the severe coral bleaching event in 1998. For instance, certain areas of Trat Province showed reduction in live coral cover of 80-90%.

Only a small number of monitoring of reef fish was carried out in Thai waters. It is very difficult to provide a clear figure of reef fish status because of high temporal variations. However, reef fish communities on reef slopes were more abundant than on reef flats. There was also a gradient of reef fish abundance from nearshore to offshore locations that was a result of reef types and certain environmental factors. No statistics of coral reef fish harvested from Thai's coral reefs are collected. Practically, most coral reefs in Thailand are used in fisheries. Many coral reefs, which locate in rural areas are used by small-scale fishermen, and shell and ornamental fish collection. They provide fishery products as important sources of both food and income.

The coral reef conditions in the Gulf of Thailand were worse after the coral bleaching in 1998. However, there are signs of recovery in many islands, depending on mainly coral recruitment.

Important Coral Reef Sites in the Gulf of Thailand

1.	Sichang Group	Chonburi Province
2.	Lan and Phai Group	Chonburi Province
3.	Sattaheep Group	Chonburi Province
4.	Samet Group	Rayong Province
5.	Chao Lao	Chanthaburi Province
6.	Mu Koh Chang	Trat Province
7.	Prachaub Khiri Khan Group	Prachaub Khiri Khan Province
8.	Chumporn Group	Chumporn Province
9.	Tao Group	Surat Thani Province
10.	Ang Thong Group	Surat Thani Province
11.	Samui and Phangan Group	Surat Thani Province
12.	Koh Nhu and Maew	Song Khla Province
13.	Koh Kra	Nakorn Srithamarat Province
14.	Koh Lao Pee	Pattani Province
15.	Koh Losin	Narathiwat Province

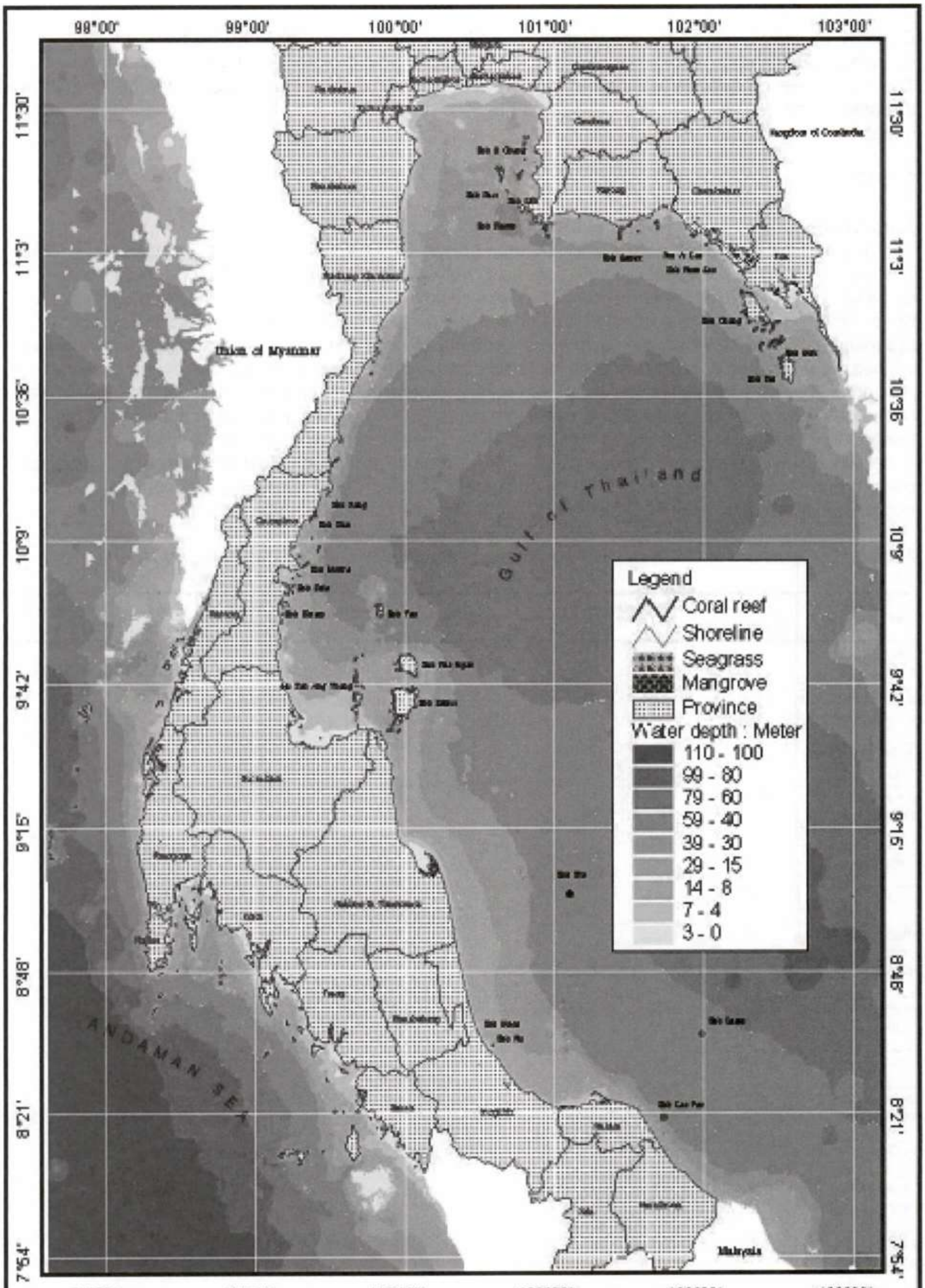

Figure 1 Distribution of coral reefs in the Gulf of Thailand.

BIODIVERSITY

Diversity of certain major groups of coral reef sites in the Gulf of Thailand, including stony corals, sponges, crustaceans, echinoderms, reef fishes, algae and threatened species is summarised in Table 3. Moreover, species lists of reef building corals, reef fishes, echinoderms and endangered and threatened species are developed based on previous surveys (Jivarat, 1985, Satapoomin, 2000) and unpublished documents as seen in Annex 1.

THREATS

Natural impacts

The first extensive coral bleaching phenomenon in the Gulf of Thailand occurred in April-June, 1998. The results from field observations obviously showed spatial variation of coral bleaching. The observed corals exhibited a variety degree of bleaching. Coral bleaching was widespread on shallow reefs. However, certain coral communities on deeper pinnacles, such as Hin Luk Bat in Trat Province, approximately 10-15m in depth, there were no signs of coral bleaching. According to the long-term studies, *Acropora* spp. and *Pocillopora damicornis* were severely affected. Several species of *Acropora* showed local extinction in certain locations. On the other hand, *Goniopora* spp. showed complete recovery after the bleaching event. Coral recovery in the inner Gulf of Thailand needs longer period of time due to low coral recruitment. However, there are large numbers of coral recruits observed in the east and the west coasts of the Gulf of Thailand. Most of them are *Pocillopora damicornis*, *Acropora* spp., *Fungia* spp. and faviid corals. Coral bleaching appeared in different degrees. Generally, most of impacted areas are now in the processes of recovery.

Table 3 Summary of biodiversity of coral reef sites in the Gulf of Thailand. (NR: no report)

Coral Reef Sites	*Hard corals*	*Coral cover (%)*	*Algae*	*Sponges*	*Crusta-ceans*	*Echino-derms*	*Reef fishes*	*Threatened species*
Chumphon Group	>120	55%	>35	NR	>304	>187	>106	5
Koh Chang, Kud and Mark	>130	40%	>69	>29	>250	>178	>113	8
Ang Thong Group	>110	55%	>45	>36	>136	>187	>122	7
Samui and Phangan Group	>40	40%	>35	NR	>136	>187	>106	11
Samet Group	>41	35%	>38	>23	>134	>98	>74	11
Sichang Group	>90	20%	>40	>66	>304	>107	>86	11
Sattaheep and Samaesarn Group	>90	33%	>40	>29	>304	>134	>75	11
Lan and Phai Group	>72	18%	>40	>33	>304	>134	>75	5
Chao Lao	>80	30%	>33	>19	>123	>107	>105	4
Prachaub Khiri Khan Group	>74	30%	>35	NR	>106	>142	>162	7
Tao Group	>79	45%	>30	NR	>136	>187	>106	7
Koh Nhu and Maew	>80	40%	>5	NR	>90	>134	>90	2
Koh Kra, Nakorn	>80	70%	>5	NR	>90	>134	>90	2
Koh Losin	>90	60%	>5	NR	>90	>134	>90	2
Koh Lao Pee	NR	NR	NR	NR	NR	NR	NR	NR

There were significant effects on coral reefs from the outbreaks of *Acanthaster planci* in the Andaman Sea in the past. High population densities of *A. planci* were also reported in certain areas of the Gulf of Thailand. However coral reef degradation in Thailand caused by *A. planci* is limited in small areas. There are no clear signs of coral damage from predation of any gastropods. Low population densities of *Duprella* sp. were observed in certain coral communities.

Extreme low tides and freshwater are additional natural disturbances, which cause severe damage to coral reefs in certain areas but in small scales. Storms and monsoons are the important causes of coral reef damage by uprooting and breaking coral colonies. For instance, the typhoons Gay and Linda hit Thailand in 1989 and 1997, respectively. These resulted in significant damage to terrestrial environment as well as coral reefs in the Gulf of Thailand.

Anthropogenic impacts

The coral reefs in Thailand support a variety of human activities that can be categorised into three main groups, i.e., tourism and recreation, fisheries-related uses and other uses. There has been a clear pattern of change in reef uses, as small-scale or traditional fisheries have gradually been replaced by tourism activities. Local fishermen have converted their boats into tour boats and collected shell for souvenir trade. This evidence can be seen in several provinces, such as Trat and Surat Thani.

Tourism and recreation activities include diving, underwater photography, glass-bottom vessels, sea walkers, and sport fishing. Tourism can result in several problems to coral reefs such as anchoring of boats on corals, accumulation of garbage, coral damaged by divers, wastewater from hotels and resorts. Living coral coverage on Nang-Yuan Island in Surat Thani, one of the most popular snorkeling sites, declined about 17% within the period of five years. Coral reefs close to beach resorts are usually used intensively for tourism-related activities. Chonburi, Rayong, Trat, Chumporn and Surat Thani are the major provinces for recreation on coral reefs in the Gulf of Thailand. Coral reefs in several localities have received very heavy tourism activities such as Pattaya, Koh Larn, Koh Samet, Koh Tao and Koh Samui. Many localities are also experiencing a rapid and steady growth in tourism, with obvious increases in coral reef-related activities. The buoy mooring projects were implemented in several areas and showed reduction of coral reef damages by anchoring.

Shell and ornamental fish collection by using chemicals are among serious problems of coral reef degradation in the Gulf of Thailand. Using of dynamite fishing was seldom observed at remote islands.

Sedimentation and wastewater pollution associated with rapid coastal development are recent and increasing severe problems in many provinces along the coastline (Sudara et al., 1991). Jetty constructions in several locations, especially in the west coast of the Gulf of Thailand, resulted in coral reef and seagrass degradation. Threat levels to coral reefs in different sites are presented in Table 4.

Table 4 Threats on coral reefs in the Gulf of Thailand.

Coral Reef Sites	Threats				
	Fishing impact	**Development impact**	**Tourism and recreation activities**	**Land-based pollution**	**Natural impact**
Sichang Group	High	High	Medium	High	Medium
Lan and Phai Group	Medium	High	High	High	High
Sattaheep Group	Medium	Medium	Low	Medium	Medium
Samet Group	Medium	High	High	Medium	High
Chao Lao, Chanthaburi Province	Medium	Medium	Low	Medium	Medium
Koh Chang	Medium	High	High	High	High
Prachaub Khiri Khan Group	High	High	Low	Medium	High
Chumphon Group	Medium	Medium	Medium	Medium	High
Tao Group	Medium	Medium	High	Low	High
Ang Thong Group	Medium	Low	Medium	Low	High
Samui and Phangan Group	Medium	Low	High	Low	High
Koh Nhu and Maew	Medium	High	Low	High	Medium
Koh Kra	Medium	Medium	Medium	Medium	Medium
Koh Losin	Medium	Low	Medium	Low	Medium

ECONOMICS VALUATION AND USES

Uses of coral reefs

Socio-economic data of certain important reef sites in the Gulf of Thailand summarised in Tables 5-6 indicate that coral reefs are used extensively in Thailand, mainly for tourist development and fisheries.

Table 5 Socio-economic data of certain important reef sites in the Gulf of Thailand.

Coral Reef Site	Coral Reef Area (Km^2)	No. of Tourist	No. of Population	No. of Fishing BoatS	Fishery Product (ton)
Mu Koh Chumporn	6.497	532.166	378,851	2,314	61,328
Mu Koh Samui	32.492	961,804	53,279	555	18,616
Mu Koh Angthong	4.259	54,323	575	-	-
Mu Koh Chang	15.558	384,733	4,773	290	95,228

Source: *Provincial Statistics, 2003.*

Table 6 Quantity of marine fishes landed at major landing places in 2000. (Unit: Ton)

Province	Total	Fish			Crustaceans			Squids and Cuttlefishes	Shell fishes
		Sub-Total Fish	Food fish	Trash fish	Shrimpa nd Prawn	Lobster	Crab		
Trat	95,228	88,773	64,324	24,449	2,162	18	503	3,771	1
Chanthaburi	2,931	2,431	1,501	930	223	-	19	258	-
Rayong	78,501	75,000	57,404	17,596	108	-	102	3,291	-
Chonburi	25,657	14,440	7,800	6,640	6,630	13	492	4,082	-
Prachuap Kirikhan	43,936	41,507	31,978	9,529	2,315	-	11	103	-
Chumporn	61,328	56,049	39,884	16,165	3,189	0	278	1,809	3
Suratthani	18,616	4,581	525	4,056	5,829	-	661	1,417	6,128
Nakhon Srithammarat	170,695	144,147	83,624	60,523	6,623	1,014	1,590	17,321	-
Songkhla	296,733	258,688	196,276	62,412	1,882	1,015	1,081	33,898	169
Pattani	280,108	268,717	198,655	70,062	1,245	343	458	9,345	-
Narathiwat	3,764	3,250	1,708	1,542	356	1	44	113	-

Source: *Department of Fisheries, 2003.*

Case studies on economic valuation

A case study on economic valuation carried out in Mu Koh Chumphon Marine National Park (Royal Forestry Department, 2003) provided values of coral reefs, including direct and indirect uses, and ecosystem service (Table 7). Total values of coral reefs of the park are 18,192,974baht/year.

Other case study used both the travel cost method and contingent valuation method to estimate the benefits of tourism on Phi Phi's coral reefs. Table 8 shows coral reef benefits based on the travel cost method. The survey found that the total benefits of the recreational services offered by Phi Phi were about 69.9 million Baht (US$1.75 million) a year for domestic visitors and 8,146.4 million Baht (US$203.66 million) a year for international visitors. Adding these two numbers up gives a figure of 8,216.4 million Baht (US$205.41 million) a year for the total recreational benefit that Phi Phi provides. Therefore, the value of Phi Phi is about 249,720 Baht (US$6,243) per ha per year (the reef area at Phi Phi is approximately 32,900ha). Loss of the site usually means loss of all future recreational opportunities, not just the current annual value. The entire future stream of annual recreational values must therefore be included. Economic theory suggests this stream of benefits, because they would occur in the future, should be discounted to make them comparable with the present. Assuming the real value of the recreational value of 8,216.4 million Baht (US$205.41 million) a year remains the same over 30 years and using a real interest rate of 5%, the present value of Phi Phi's recreational benefits is 126,280 million Baht (US$3,157 million). It is apparent from this analysis that the local and national government in Thailand can justify larger annual budget allocations for the management of coral reefs.

Table 7 Valuation of coral reefs in Mu Koh Chumphon Marine National Park.

Coral reef utilization	Resources	*Price/unit*	*Value/year (Baht)*
Fisheries products (local community consumption)	72,476kg	50 Baht/kg.	3,623,800
Fisheries products (commercial species)	2,719.3kg.	100 Baht/kg.	271,930
Tourism revenue (long stay)	4,815.15 people	732.39 Baht/people	3,526,567.71
Tourism revenue (one day trip)	8,059.58 people	127.72 Baht/people	1,029,369.56
Indirect value from resources satisfaction	12,808.54 people	624.67 Baht/people	8,001,110.68
Coastal protection	3.6239km^2	480,000 Baht/km^2	1,739,472
Ecological service	3.6239km^2	2 00.00 Baht/km^2	724.78
	Total		18,192,974.73

Table 8 Coral reef benefits based on the travel cost method. (Note: US$1 = 40 Baht

Sample size	CS per visit	Number of visitors *(1998)*	Total benefits
Domestic (n = 630)	3,403.55 Baht (US$85)	20,540	69.9 million Baht (US$1.75 million)
International (n = 128)	59,760 Baht (US$1,494)	136,277	8,146.4 million Baht (US$203.66 million)

Table 9 shows coral reef benefits based on the contingent valuation method. The valued derived by this method differs from the values previously present, as only the coral sites were evaluated and not the entire Phi Phi Islands as in the travel cost measures. It was found that the mean maximum willingness to pay for domestic visitors was 287 Baht (US$7.17) per visit. For international visitors the figure was 286 Baht (US$7.15) per visit. From this it was calculated that the total value of Phi Phi's coral reefs were 5.89 million Baht (US$0.147 million) a year for domestic visitors and 49.6 million Baht (US$1.24 million) a year for international visitors. This study also used CVM to calculate the mean willingness to pay of domestic vicarious users (people who value the reef without visiting it) – 634 Baht (US$15.85) per person – and from this the total value (use and non-use) of the reefs. This was estimated to be 19,840 million Baht (US$496 million) a year. Therefore, the benefit values (use and non-use) of Phi Phi's coral reefs were estimated to be 19,895 million Baht (US$497.38 million) a year, averaging 604,720 Baht (US$15,118) per ha per year.

The study also found that the reefs studied could generate large economic returns through leisure pursuits and that tourists were willing to pay for conservation measures. It suggests a number of levies and charges that could help remove tourist pressure from the reefs and help pay for their conservation.

Table 9 Coral reef benefits based on the contingent valuation method.

	Users			Non-users
	Domestic (n = 400)	International (n = 128)		Domestic (n = 200)
WTP per visit	287 Baht (US$7.17)	286 Baht (US$7.15)	WTP per person	634 Baht (US$15.85)
Number of visitors (1998)	20,540	136,277	Size of labour force (1998)	31.3 million
Total benefits	5.89 million Baht (US$.147 million)	49.6 million Baht (US$1.24 million)	Total benefits	19,840 million Baht (US$496 million)

Regarding willingness to pay the utilisation of coral reef resource on tourism, a case study was implemented in Ko Chang National Park, Trat Province. The purpose of this research was to study the Willingness to Pay (WTP) factors that affect the utilization of coral resource by tourism. Derived results might present appropriate guidelines to determine admission fees for the utilisation of the resource. A Survey Research method was employed in this study. The study sample comprised of 103 tourists who viewed the coral reef resource, and 109 tourists that did not, 22 businesses that supplied equipment for coral viewing as well as 24 businesses that did not, and 206 local residents. The WTP study was achieved by using travel cost method and contingent valuation method. All variable factors such as age, average monthly income, travel cost with time value, etc., were analyzed using multiple regression analysis.

The WTP for use values of coral resource utilizing for tourism under travel cost and contingent valuation methods were 219,808,391 baht/year and 1,026,027,000 baht/year respectively. The total economic value was 7,185,500,182 baht/year. Average monthly income, attitude toward coral resource and presentation WTP had significant positive effects on WTP for the use value. However, age of tourists as another significant independent variable showed an opposite outcome. The WTP for option value had significant positive relationship with age, average monthly income, travel cost with time value, knowledge and attitude. Average monthly income, frequency of visits, knowledge, attitude, and information received had positive but level of education had negative relationship with the WTP for existence value. All variable were evaluated at $\alpha = 0.05$.

The guidelines for admission fees for coral resource utilisation for tourism at Ko Chang National Park, as developed based on this study indicate that the government might need to set up admission fees about 52.92 baht/time for a tourist who visit coral resource, and about 3,398.28 baht/year for businesses that supply equipment for such activities.

MANAGEMENT

Overview of Coral Reef Management

Coral reef management in Thailand rests on laws and regulations that apply to all coral reefs and additional measures applicable only to marine protected areas. In recent years, central agencies, provincial governments and the private sectors have undertaken non-regulatory actions aimed at improving coral reef conditions through restoration, preventive measures and education.

Several laws are used to protect coral reefs in Thailand, e.g., the Fisheries Law of 1947, the National Park Act of 1961, the Enhancement and Conservation of National Environmental Quality Act (NEQA) of 1975, etc. These regulations are mainly enforced by the Department of Fisheries (DOF) and Marine National Parks. There have been problems in enforcing coral reef protection regulations. For example, the language of the law and the subsequent regulations are often unclear or incomplete. Marine National Parks in Thailand include significant reef areas. Most of the parks containing reefs have been designated in the Andaman Sea, which only a few sites designated in the Gulf of Thailand. Together with the Fisheries Protected Areas, approximately 60% of Thailand's significant coral reefs are included a protected area.

Several institutional and operational constraints have, however, limited the effectiveness of Thailand's network of protected areas in preserving coral reef habitat. These include:

- The size of the areas designated and the boundaries have been too broad or have not corresponded to resource protection priorities;
- There have been serious conflicts between park designation and traditional uses of marine resources, particularly fisheries;
- Local economic and social priorities have been overlooked in the park management and development process;
- Jurisdiction over marine resources is unclear and there have been apparent conflicts with fisheries regulations; and
- The emphasis of marine park management has been on accommodating visitor use rather than on resource protection, marine interpretation and enforcement.

Non-regulatory measures

Public support for coral reef management increased dramatically the late 1980's. This support has come in part form the extensive media coverage of both the beauty and degradation of Kingdom's coral reefs. Commitment to coral reef conservation has also grown in response to direct action taken at both national and local levels to reverse trends in coral reef degradation. These actions have largely been voluntary. They depend on individuals, businesses and government agencies working together to solve problems. Such voluntary efforts are called "non-regulatory measures".

Non-regulatory measures can include education and scientific activities as well as direct management actions such as mooring buoy installation. Several organisations have led the effort to increase public awareness about importance of coral reefs The human activities that are leading to their degradation and actions can be taken to conservation this valuable habitat. This campaign has reached most of Thailand's mass media.

The Tourism Authority of Thailand and volunteer associations of divers and tour boat operators have cooperated to educate pilots and escort guides in coral reef ecology and ways to avoid damaging reefs. The results of such efforts have been impressive in terms of change of behavior and increase of commitment to conservation. The Nation Park Division is beginning to include coral reefs in its park interpretive programs; and the Department of Fisheries, through its extension program, has offered conservation education to reef fishermen.

Cooperation among coral reef scientists in Thailand has been extensive and is essential to the national strategy formulation process. Researchers have worked together to document reef conditions in Thailand through the ASEAN-Australian baseline study and the coral reefs project of Department of Fisheries.

Management Models and Marine National Parks

There are only a few case studies of community-based management on coral communities in Thailand such as Had Chaolao in Chantaburi Province where local people manage coral communities for tourism. There are currently 7 Marine National Parks in the Gulf of Thailand (Figure 2) which play a major role on coral reef management in Thailand, harboring about 38% of the total area of coral reefs in the gulf (Table 10). Based on the report by Department of Fisheries in 1999, conditions of coral reefs in the marine parks are classified mostly as fair to excellent (Table 11). The general organisation chart of marine national parks are showed in Figure 3. There are also several fisheries sanctuaries, which are controlled by Department of Fisheries. Many islands, especially in Chonburi Province, are managed by Thai Royal Navy. Other islands, mostly in Chumporn Province, assigned for bird nest concession have been recognised as areas with the good reefs.

Coral Reef Zoning

All major coral reefs in the Gulf of Thailand are previously assigned to one of four management categories as follows:

- General Use Zone
- Intensive Tourism Zone
- Ecotourism Zone
- Ecosystem Reserved Zone

A total of 290 coral reef sites is classified by using the above criteria. The majority of coral reefs in the Gulf of Thailand is classified as ecotourism zone (Table 12).

Table 10. Coral reefs in national parks in the Gulf of Thailand.

Province	Coral reef area (km^2)	Coral reef area in national parks		National park
		(km^2)	(%)	
Trat	15.89	4.84	30.46	Mu Koh Chang
Chantaburi	0.72	-	-	None
Rayong	3.50	2.71	77.4	Khao Laem Ya – Mu Koh Samet
Chonburi	7.59	-	-	None
Prachuap Khirikhan	2.04	0.22	10.80	Had Warakorn Khao Sam Roi Yod
Chumporn	6.50	6.14	94.50	Mu Koh Chumporn
Surat Thani	38.67	14.35	37.11	Mu Koh Angthong Tarnsadej
Total	**74.91**	**28.26**	**37.72**	7 national parks

Source: *Marine National Park Division (excluding marine national parks at Had Khanom- Mu Koh Talay Tai and Ao Manao).*

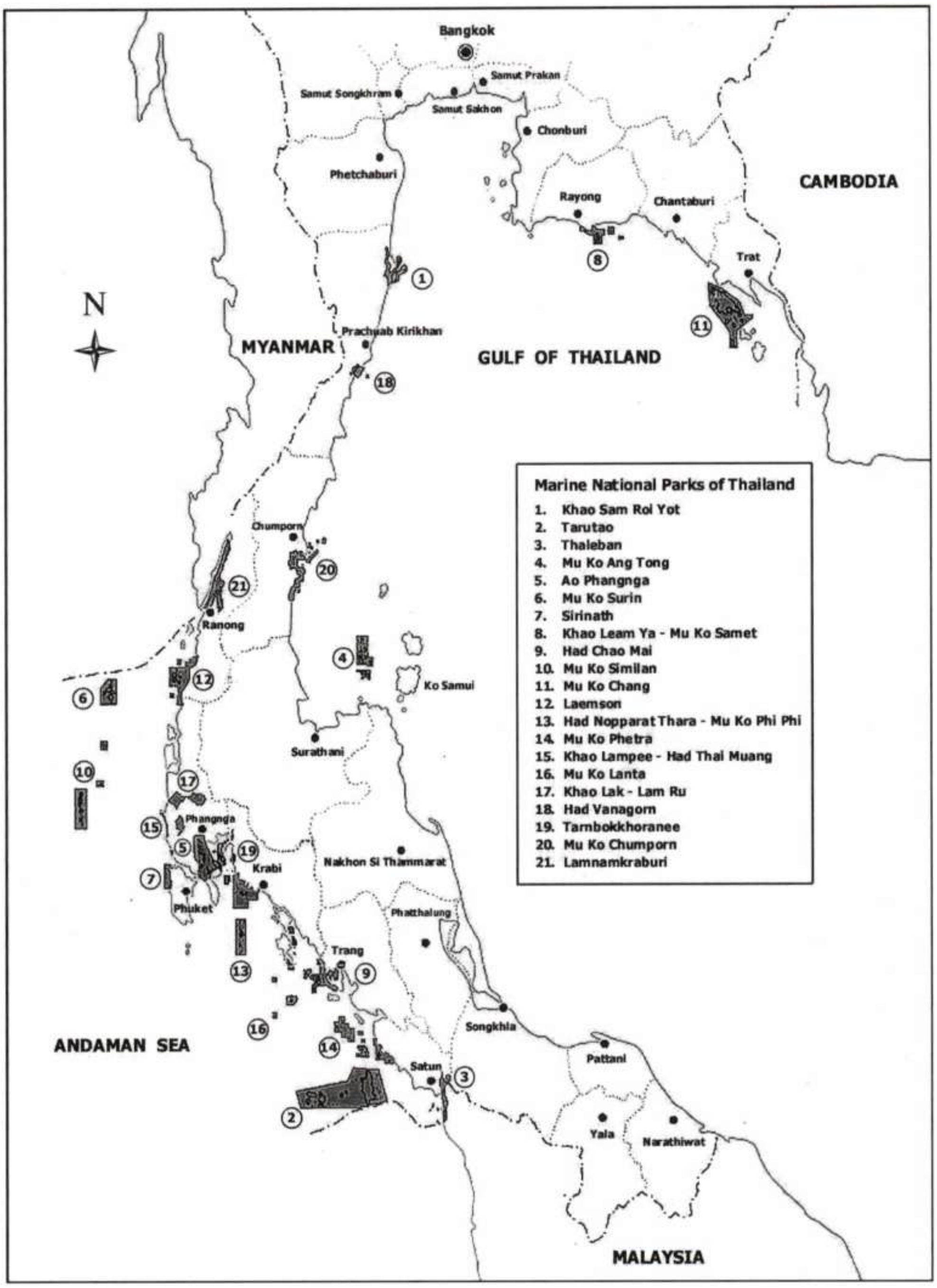

Figure 2 Map of Marine National Parks in Thailand.

Table 11 Coral reef conditions in Marine National Parks in the Gulf of Thailand.

Marine National Park	Coral reef area (km^2)	Coral reef conditions				
		Excellent (%)	Good (%)	Fair (%)	Poor (%)	Very poor (%)
Mu Koh Chang	4.84	23.50	31.21	25.67	9.75	9.87
Mu Koh Samet	2.71	12.57	36.73	29.66	2.30	18.74
Khao Sam Roi Yod	0.14	30.00	-	-	-	70.00
Had Warakorn	0.08	60.00	40.00	-	-	-
Mu Koh Chumporn	6.14	41.17	22.38	29.30	3.09	4.06
Mu Koh Angthong	3.31	31.66	36.43	20.69	5.33	5.89
Tarnsaej	11.04	5.20	56.10	33.70	2.5	2.50

Source: *Department of Fisheries, 1999.*

Table 12 Coral reef zoning in the Gulf of Thailand.

Province	Coral Reef Zoning (Number of island/site)				Total
	General Use Zone	Intensive Tourism Zone	Ecotourism Zone	Ecosystem Reserved Zone	
Chonburi	6	2	33	5	46
Rayong	2	4	12	0	18
Chantaburi	0	0	1	3	4
Trad	3	0	34	5	42
Prachuap Khirikhan	9	0	6	4	19
Chumporn	18	0	44	2	64
Surat Thani	10	4	71	2	87
Nakhon Sithammarat	0	0	1	0	1
Songkhla	4	0	2	0	6
Pattani	2	0	0	0	2
Naratiwat	0	0	1	0	1
Total	54	10	205	21	290

Management Capacity for Coral Reefs

There are many institutions involved in coral reef management in Thailand, including:

- Office of Environment Policy and Planning
- Pollution Control Department
- Chulalongkorn University (Department of Marine Science and Aquatic Resources Research Institute)
- Ramkhamhaeng University (Marine Biodiversity Research Group)
- Kasetsart University (Faculty of Fisheries)
- Burapha University (Department of Aquatic Science and Marine Science Institute)
- Prince of Songkla University (Department of Biology)
- Department of Fisheries
- Department of Marine and Coastal Resources (Marine and Coastal Resources Research Center, Center Gulf of Thailand, Research, Marine and Coastal Resources Research Center, Eastern Gulf of Thailand and Phuket Marine Biological Center)
- Marine National Park Division (21 Marine National Parks)
- Royal Thai Navy
- Chulabhorn Research Institute
- Reef Check Thailand

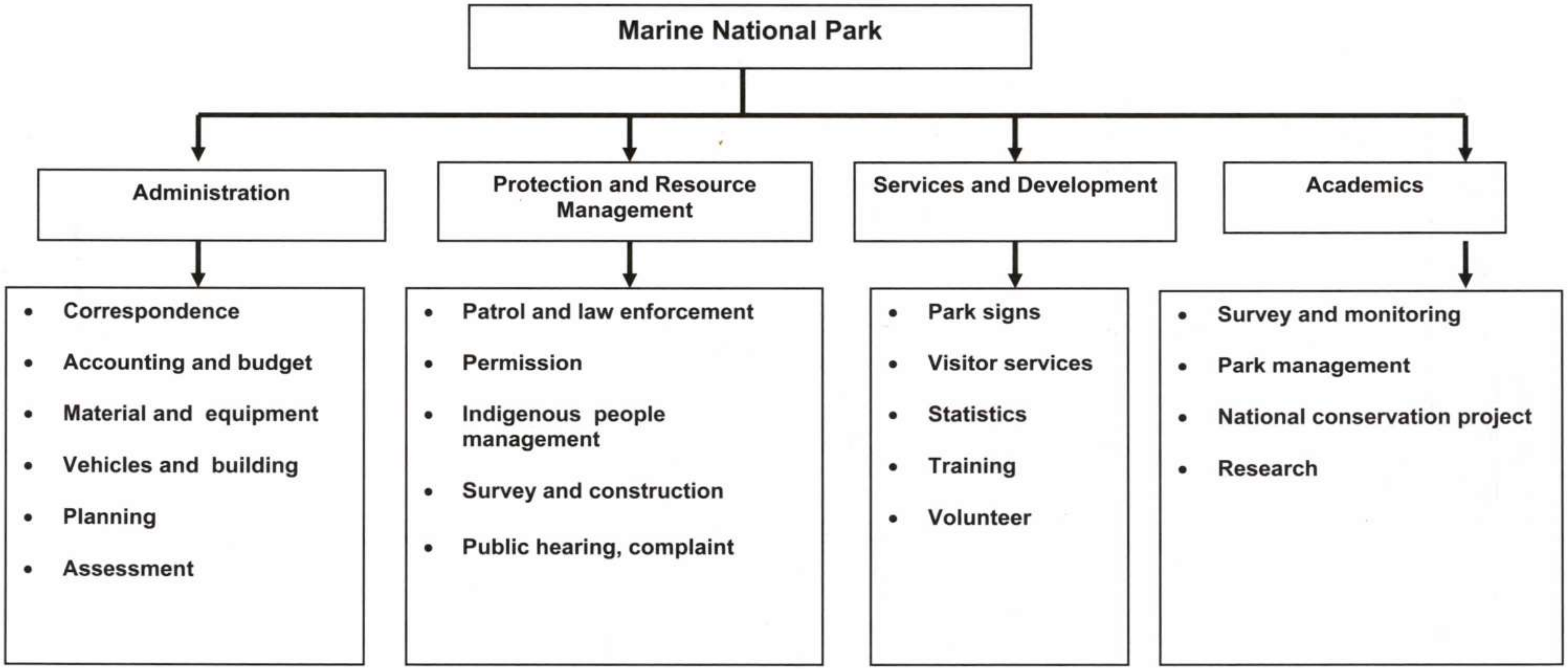

Figure 3 General organisation chart of marine national park in Thailand.

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ANNEX 1
List of Coral Reef Species Recorded in the Gulf of Thailand

Table 1 Common hard corals found in the Gulf of Thailand.

Family	Scientific name	Common name
Astrocoeniidae	*Stylocoeniella armata*	Thom coral
Pocilloporidae	*Pocillopora damocornis*	Cauliflower coral
	Pocillopora verucosa	Cauliflower coral
Acroporidae	*Acropora humilis*	Staghorn coral
	Acropora cf. *digitifera*	Staghorn coral
	Acropora formosa	Staghorn coral
	Acropora muricata	Staghorn coral
	Acropora nobilis	Staghorn coral
	Acropora micropthalma	Staghorn coral
	Acropora millepora	Staghorn coral
	Acropora pulchra	Staghorn coral
	Acropora hyacinthus	Staghorn coral
	Acropora nasuta	Staghorn coral
	Acropora cytherea	Staghorn coral
	Acropora florida	Staghorn coral
	Acropora valida	Staghorn coral
	Astreopora gracilis	Starflower coral
	Astreopora myriopthalma	Starflower coral
	Astreopora ocellata	Starflower coral
	Montipora aequituberculata	Pore coral
	Montipora grisea	Pore coral
	Montipora foliosa	Pore coral
	Montipora efflorescens	Pore coral
	Montipora hispida	Pore coral
	Montipora cebuensis	Pore coral
	Montipora danae	Pore coral
	Montipora digitata	Pore coral
	Montipora informis	Pore coral
	Montipora millepora	Pore coral
	Montipora monasteriata	Pore coral
	Montipora peltiformis	Pore coral
	Montipora tuberculosa	Pore coral
Acroporidae	*Montipora hoffmeisteri*	Pore coral
	Montipora spongodes	Pore coral
Fungiidae	*Diaseris* sp.	
	Fungia fungites	Mushroom coral
	Fungia echinata	Mushroom coral
	Fungia surpulosa	Mushroom coral
	Fungia scaraba	Mushroom coral
	Fungia granulose	Mushroom coral
	Fungia concinna	Mushroom coral
	Fungia repanda	Mushroom coral
	Fungia poumotensis	Mushroom coral
	Fungia corona	Mushroom coral
	Herpetoglossa simplex	Coarse boomerang coral
	Herpolitha limax	Striate boomerang coral
	Polyphyllia talpina	Joker's boomerang coral

Table 1*cont.* Common hard corals found in the Gulf of Thailand.

Family	Scientific name	Common name
	Sandalolitha robusta	
	Podabacia cf. *crustacean*	Bracket coral
	Lithophyllon edwardsi	Stone-leaf coral
Poritidae	*Porites australiaensis*	
	Porites labata	
	Porites lutea	Mountain coral
	Porites cylindrical	Finger coral
	Porites lichen	Hump coral
	Porites rus	Wrinkle coral
	Porites solida	Hump coral
	Goniopora djiboutiensis	Anemone coral
	Goniopora columna	Anemone coral
	Goniopora fructicosa	Anemone coral
	Goniopora lobata	Anemone coral
	Goniopora somaliensis	Anemone coral
	Goniopora tenuidens	Anemone coral
Agariciidae	*Oulastrea crispapa*	Intermediate valley coral
	Oulastrea heliopora	Intermediate valley coral
	Leptoseris scabra	Porcelain coral
Agariciidae	*Coeloseris mayeri*	
	Pachyseris speciosa	Serpent coral
	Pavona cactus	Flower coral
	Pavona decussate	Flower coral
	Pavona frondifera	Flower coral
	Pavona varians	Flower coral
Siderstreidae	*Pseudosiderastrea tayamai*	
	Psammocora contiqua	Petal-like coral
	Psammocora nierstraszi	Petal-like coral
	Psammocora profundacella	Petal-like coral
	Psammocora digitata	Petal-like coral
Oculinidae	*Galaxea astreata*	Galaxy coral
	Galaxea fascicularis	Octopus coral
Faviidae	*Barabattoia amicorum*	Knob coral
	Favia pallida	Ring coral
	Favia favus	Ring coral
	Favia speciosa	Ring coral
	Favia matthaii	Ring coral
	Favia maxima	Ring coral
	Favia rotumana	Ring coral
	Favites abdita	Larger star coral
	Favites chinensis	Larger star coral
	Favites complanata	Larger star coral
	Favites flexuosal	Larger star coral
	Favites halicora	Larger star coral
	Favites pentagona	Larger star coral
	Favites russelli	Larger star coral
	Goniastrea aspera	Honey comb coral
	Goniastrea australiaensis	Honey comb coral
	Goniastrea edwardsi	Honey comb coral
	Goniastrea favulus	Honey comb coral

Table 1*cont.* Common hard corals found in the Gulf of Thailand.

Family	Scientific name	Common name
	Goniastrea palauensis	Honey comb coral
	Goniastrea retiformis	Honey comb coral
	Goniastrea pectinata	Honey comb coral
Faviidae	*Platygyra daedalea*	Brain coral
	Platygyra lamellina	Brain coral
	Platygyra sinensis	Brain coral
	Leptoria phrygia	Brain coral
	Montastrea curta	
	Montastrea magnistellata	
	Montastrea valenciennesi	
	Leptastrea purpurca	Crust coral
	Leptastrea tranversa	Crust coral
	Cyphastrea serailia	Small star coral
	Cyphastrea chalcidicum	Small star coral
	Cyphastrea microphthalma	Small star coral
	Echinopora lamellosa	Spiny pored coral
	Diploastrea heliopora	Double star coral
Merulinidae	*Hydnophora exesa*	Jack-fruit spined coral
	Hydnophora microconos	Jack-fruit spined coral
	Merulina ampliata	Spiny cabbage coral
Mussidae	*Acanthastrea hillae*	Starry cup coral
	Lobophyllia hemprichii	Lobed cup coral
	Lobophyllia hattai	Lobed cup coral
	Symphyllia recta	Brain coral
	Symphyllia radians	Brain coral
Pectinidae	*Pectinia lactuca*	Lettuce coral
	Pectinia paeonia	Lettuce coral
	Echinophyllia aspera	Spiny encrusting coral
	Oxypora lacera	Spiny plate coral
Dendrophylliidae	*Turbinaria peltata*	Disc coral
	Turbinaria frondens	Disc coral
	Dendrophyllia micranthus	Tree coral
Caryophylliidae	*Plerogyra sinuosa*	Rounded bubblegum coral
Total	**130**	

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Table 1 Common hard corals found in the Gulf of Thailand.

Family	Scientific name	Common name
Astrocoeniidae	*Stylocoeniella armata*	Thom coral
Pocilloporidae	*Pocillopora damocornis*	Cauliflower coral
	Pocillopora verucosa	Cauliflower coral
Acroporidae	*Acropora humilis*	Staghorn coral
	Acropora cf. *digitifera*	Staghorn coral
	Acropora formosa	Staghorn coral
	Acropora muricata	Staghorn coral
	Acropora nobilis	Staghorn coral
	Acropora micropthalma	Staghorn coral
	Acropora millepora	Staghorn coral
	Acropora pulchra	Staghorn coral
	Acropora hyacinthus	Staghorn coral
	Acropora nasuta	Staghorn coral
	Acropora cytherea	Staghorn coral
	Acropora florida	Staghorn coral
	Acropora valida	Staghorn coral
	Astreopora gracilis	Starflower coral
	Astreopora myriopthalma	Starflower coral
	Astreopora ocellata	Starflower coral
	Montipora aequituberculata	Pore coral
	Montipora grisea	Pore coral
	Montipora foliosa	Pore coral
	Montipora efflorescens	Pore coral
	Montipora hispida	Pore coral
	Montipora cebuensis	Pore coral
	Montipora danae	Pore coral
	Montipora digitata	Pore coral
	Montipora informis	Pore coral
	Montipora millepora	Pore coral
	Montipora monasteriata	Pore coral
	Montipora peltiformis	Pore coral
	Montipora tuberculosa	Pore coral
Acroporidae	*Montipora hoffmeisteri*	Pore coral
	Montipora spongodes	Pore coral
Fungiidae	*Diaseris* sp.	
	Fungia fungites	Mushroom coral
	Fungia echinata	Mushroom coral
	Fungia surpulosa	Mushroom coral
	Fungia scaraba	Mushroom coral
	Fungia granulose	Mushroom coral
	Fungia concinna	Mushroom coral
	Fungia repanda	Mushroom coral
	Fungia poumotensis	Mushroom coral
	Fungia corona	Mushroom coral
	Herpetoglossa simplex	Coarse boomerang coral
	Herpolitha limax	Striate boomerang coral
	Polyphyllia talpina	Joker's boomerang coral

Table 1*cont.* Common hard corals found in the Gulf of Thailand.

Family	Scientific name	Common name
	Sandalolitha robusta	
	Podabacia cf. *crustacean*	Bracket coral
	Lithophyllon edwardsi	Stone-leaf coral
Poritidae	*Porites australiaensis*	
	Porites labata	
	Porites lutea	Mountain coral
	Porites cylindrical	Finger coral
	Porites lichen	Hump coral
	Porites rus	Wrinkle coral
	Porites solida	Hump coral
	Goniopora djiboutiensis	Anemone coral
	Goniopora columna	Anemone coral
	Goniopora fructicosa	Anemone coral
	Goniopora lobata	Anemone coral
	Goniopora somaliensis	Anemone coral
	Goniopora tenuidens	Anemone coral
Agariciidae	*Oulastrea crispapa*	Intermediate valley coral
	Oulastrea heliopora	Intermediate valley coral
	Leptoseris scabra	Porcelain coral
Agariciidae	*Coeloseris mayeri*	
	Pachyseris speciosa	Serpent coral
	Pavona cactus	Flower coral
	Pavona decussate	Flower coral
	Pavona frondifera	Flower coral
	Pavona varians	Flower coral
Siderstreidae	*Pseudosiderastrea tayamai*	
	Psammocora contiqua	Petal-like coral
	Psammocora nierstraszi	Petal-like coral
	Psammocora profundacella	Petal-like coral
	Psammocora digitata	Petal-like coral
Oculinidae	*Galaxea astreata*	Galaxy coral
	Galaxea fascicularis	Octopus coral
Faviidae	*Barabattoia amicorum*	Knob coral
	Favia pallida	Ring coral
	Favia favus	Ring coral
	Favia speciosa	Ring coral
	Favia matthaii	Ring coral
	Favia maxima	Ring coral
	Favia rotumana	Ring coral
	Favites abdita	Larger star coral
	Favites chinensis	Larger star coral
	Favites complanata	Larger star coral
	Favites flexuosal	Larger star coral
	Favites halicora	Larger star coral
	Favites pentagona	Larger star coral
	Favites russelli	Larger star coral
	Goniastrea aspera	Honey comb coral
	Goniastrea australiaensis	Honey comb coral
	Goniastrea edwardsi	Honey comb coral
	Goniastrea favulus	Honey comb coral

Table 1*cont.* Common hard corals found in the Gulf of Thailand.

Family	Scientific name	Common name
	Goniastrea palauensis	Honey comb coral
	Goniastrea retiformis	Honey comb coral
	Goniastrea pectinata	Honey comb coral
Faviidae	*Platygyra daedalea*	Brain coral
	Platygyra lamellina	Brain coral
	Platygyra sinensis	Brain coral
	Leptoria phrygia	Brain coral
	Montastrea curta	
	Montastrea magnistellata	
	Montastrea valenciennesi	
	Leptastrea purpurca	Crust coral
	Leptastrea tranversa	Crust coral
	Cyphastrea serailia	Small star coral
	Cyphastrea chalcidicum	Small star coral
	Cyphastrea microphthalma	Small star coral
	Echinopora lamellosa	Spiny pored coral
	Diploastrea heliopora	Double star coral
Merulinidae	*Hydnophora exesa*	Jack-fruit spined coral
	Hydnophora microconos	Jack-fruit spined coral
	Merulina ampliata	Spiny cabbage coral
Mussidae	*Acanthastrea hillae*	Starry cup coral
	Lobophyllia hemprichii	Lobed cup coral
	Lobophyllia hattai	Lobed cup coral
	Symphyllia recta	Brain coral
	Symphyllia radians	Brain coral
Pectinidae	*Pectinia lactuca*	Lettuce coral
	Pectinia paeonia	Lettuce coral
	Echinophyllia aspera	Spiny encrusting coral
	Oxypora lacera	Spiny plate coral
Dendrophylliidae	*Turbinaria peltata*	Disc coral
	Turbinaria frondens	Disc coral
	Dendrophyllia micranthus	Tree coral
Caryophylliidae	*Plerogyra sinuosa*	Rounded bubblegum coral
Total	**130**	

Table 2 Common reef fish found in the Gulf of Thailand.

Family	Scientific name	Common name
Rhincodontidae	*Rhincodon typus*	Whale shark
Dastidae	*Taenidae lymna*	Blue spotted ribbon tail ray
Atherinidae	*Atherinomonus* sp.	Silverside
Kyphosidae	*Kyphosus cinerascens*	Highfin rudderfish
Apogonidae	*Archamia fucata*	Orange-line cardinalfish
	Archamia goni	cardinalfish
	Apogon cyanosoma	Yellow-striped cardinalfish
	Apogon taeniophorus	Bandfin cardinalfish
	Cheilodipterus artus	Lined cardinalfish
	Cheilodipterus macrodon	Large-toothed cardinalfish
	Cheilodipterus quinquelineatus	Five-lined cardinalfish
Caesionidae	*Caesio caerulaurea*	Scissor-tailed fusilier
	Caesio cunning	Deep-bodied fusilier
	Pterocaesio chrysozoma	Goldband fusilier
Chaetodontidae	*Chaetodon octofasciatus*	Eight-banded butterflyfish
	Chaetodon weibeli	Weibeli's butterflyfish
	Chelmon rostratus	Beaked butterflyfish
	Hemiochus acuminatus	Longfin bannerfish
Diodontidae	*Diodon histrix*	Porcupinefish
	Diodon liturosus	Blach-blotch porcupinefish
Ephippidae	*Platax teira*	Longfin spadefish
Gobiosocidae	*Diademichthys lineatus*	Urchin clingfish
Gobiidae	*Amblygobius noctumes*	Nocturn goby
	Cryptocentrus cinctus	Yellow prawn-goby
	Cryptocentrus fasciatus	Barred prawn-goby
	Cryptocentrus leptocephalus	Leptocephalus prawn-goby
	Cryptocentrus strigilliceps	Target prawn-goby
	Cryptocentrus sp.1	Goby
	Cryptocentrus sp.2	Goby
	Ctenogobiops pomastictus	Gold-specked prawn-goby
	Istigobius ornatus	Ornate goby
	Mahidolia mystacina	Flagfin prawn-goby
Gobiidae	*Valenciennea mularis*	Mural goby
Grammistidae	*Diploprion bifasciatum*	Two-banded soapfish
Haemulidae	*Diagramma pictum*	Slatey sweetlips
	Plectorhinchus albovittatus	Giant sweetlips
	Plectorhinchus gibbosus	Gibbus sweetlips
	Plectorhinchus chaetodonoides	Harlequin sweetlips
	Plectorhynchus picus	Spotted sweetlips
Holocentridae	*Myripristis hexagona*	Doubletooth soldierfish
	Sargocentrum rubrum	Redcoat
Kyhposidae	*Kyphosus vaigiensis*	Lowfin rudderfish
Labridae	*Cheilinus chlorourus*	Floral wrasse
	Cheilinus fasciatus	Red-banded wrasse
	Cheilinus trilobatus	Tripletail wrasse
	Choerodon schoenleinii	Blackspot wrasse
	Diproctacanthus xanthurus	Wandering cleaner wrasse
	Epibulus insidiator	Slingjaw wrasse
	Halichoeres argus	Argus wrasse
	Halichoeres chloropterus	Postel-green wrasse

Table 2*cont.* Common reef fish found in the Gulf of Thailand.

Family	Scientific name	Common name
	Halichoeres hortulanus	Checkerboard wrasse
	Halichoeres margaritarceus	Weedy surge wrasse
	Halichoeres marginatus	Dusky wrasse
	Halichoeres melanulus	Pin striped wrasse
	Halichoeres nebulosus	Nebulosus wrasse
	Halichoeres nigrescen	Diamond wrasse
	Halichoeres purpurescen	Purple striped wrasse
	Hemigymnus fasciatus	Barred thicklip
	Hemigymnus melapterus	Blackedge thicklip
	Labroides dimidiatus	Cleaner wrasse
	Novaculichthys taeniourus	Dragon wrasse
	Oxycheilinus digrammus	Bandcheek wrasse
	Stethojulis interrupta	Cutribbon wrasse
	Stethojulis trilineata	Three-blue line wrasse
Lutjanidae	*Lutjanus argentimaculatus*	River snapper
	Lutjanus decussatus	Checkered snapper
	Lutjanus fulviflamma	Flame tail snapper
Lutjanidae	*Lutjanus lemniscatus*	Snapper
	Lutjanus monostigma	Onespot snapper
	Lutjanus russelli	Russel's snapper
	Lutjanus vitta	One-lined snapper
Microdesmidae	*Pteriotris microlepsis*	
Mullidae	*Parupeneus indicus*	Indian goatfish
	Upeneus tragula	Blackstriped goatfish
Muraenidae	*Gymnothorax* sp.	Moray
	Siderea thyrsoidea	Moray
Nemipteridae	*Scolopsis bilineatus*	Twoline spinecheek
	Scolopsis ciliatus	Saw-jawed spinecheek
	Scolopsis magaritifer	Pearly spinecheek
	Scolopsis monogramma	Monogrammed monocle bream
Ostraciidae	*Ostracion cubicus*	Yellow boxfish
Pempheridae	*Pempheris oualensis*	Copper sweeper
Pomacanthidae	*Pomacanthus annularis*	Bluering anglefish
Pomacentridae	*Abudefduf bengalesis*	Bengal sergeant
	Abudefduf notatus	Yellow-tail sergeant
	Abudefduf sexfasciatus	Scissor-tail sergeant
	Abudefduf sordidus	Black-spot sergeant
	Abudefduf vaigiensis	Indo-pacific sergeant
	Amblyglyphidodon curacao	Staghorn damsel
	Amphiprion peridarion	Pink anemone fish
	Cheiloprion labiatus	Big-lip damsel
	Chromis atripectoralis	Black-axil chromis
	Chromis cinerascens	Green chromis
	Chrysiptera unimaculata	One spotted chromis
	Dacyllus reticulatus	Reticulated dascyllus
	Dacylluss trimaculatus	Three-spotted dascyllus
	Neoglyphidodon melas	Black damsel
	Neopomacentrus cyanomos	Regal damoiselle
	Neopomacentrus filamentosus	Brown damoiselle

Table 2*cont.* Common reef fish found in the Gulf of Thailand.

Family	Scientific name	Common name
	Plectoglyphidodon lacrymatus	Jewel damsel
	Pomacentrus alexanderae	Alexander's damsel
Pomacentridae	*Pomacentrus chrysurus*	Whitetail damsel
	Pomacentrus coelestis	Neon damsel
	Pomacentrus cuneatus	Wedge spotted damsel
	Pomacentrua moluccensis	Lemon damsel
Scaridae	*Scarus frenatus*	Bridled parrotfish
	Scarus ghobban	Bluebarred parrotfish
	Scarus niger	Swarthy parrotfish
	Scarus prasiognathos	Greenthroat parrotfish
	Scarus rivulatus	Surf parrotfish
Serranidae	*Anyperodon leucogrammicus*	Slender grouper
	Cephalopholis argus	Peacock grouper
	Cephalopholis boenak	Chocolate hind
	Cephalopholis cyanostigma	Bluespotted hind
	Cephalopholis formosa	Bluelined hind
	Cephalopholis sp.	Grouper
	Epinephelus rivulatus	Halfmoon grouper
	Epinephelus fasciatus	Blacktip grouper
	Epinephelus quoyanus	Longfin grouper
	Plectopomus maculatus	Spotted coral grouper
Siganidae	*Siganus corallinus*	Coral rabbitfish
	Siganus guttatus	Yellow spotted rabbitfish
	Siganus javus	Java rabbitfish
	Siganus punctatus	Goldspotted rabbitfish
	Siganus vermiculatus	Vermiculate rabbitfish
	Siganus virgatus	Virgate rabbitfish
Sphyraenidae	*Sphyraena baracuda*	Great barracuda
	Sphyraena genie	Blackfin barracuda
	Sphyraena obtusata	Barracuda
Total	**113**	

Table 3 Echinoderms found in the Gulf of Thailand.

CRINOIDEA	**Order SPINULOSIDA**
Order COMATULIDA	**Echinasteridae**
Mariametridae	41. *Echinaster luzonica* (Gray, 1840)
1. *Dichrometra bimaculata* (Carpenter,1881)	***OPHIUROIDEA***
2. *Dichrometra tenuicirra* A.H. Clark, 1912	**Order PHRYNOPHIURIDA**
3. *Lamprometra palmata* (Müller, 1841)	**Ophiomyxidae**
4. *Liparometra articulata* (Müller, 1849)	42. *Ophiomyxa irregularis* Koehler, 1898
5. *Stephanometra oxycantha* (Hartluab, 1890)	**Euryalidae**
6. *Stephanometra spicata* (Carpenter, 1881)	43. *Euryale aspera* Lamarck, 1816
ASTEROIDEA	**Asteronychidae**
Order PAXILLOSIDA	44. *Asteronyx loveni* Müller & Troschel, 1842
Luidiidae	*Order* OPHIURIDA
7. *Luidia maculata* Müller and Troschel, 1842	**Amphiuridae**
8. *Luidia penangensis* de Loriol, 1891	45. *Amphilycus scripta* (Koehler, 1904)
Astropectinidae	46. *Amphioplus relictus* (Koehler, 1905)
9. *Astropecten granulatus* Müller and Troschel, 1842	47. *Amphioplus (Amphichilus) cesareus* (Koehler, 1905)
10. *Astropecten fasciatus* Döderlein, 1926	48. *Amphioplus (Lymanella) depressa* (Ljungman, 1867)[12]
11. *Astropecten indicus* Döderlein, 1888	49. *Amphipholis misera* (Koehler, 1899)
12. *Astropecten hartmeyeri* Döderlein, 1917[4]	50. *Amphipholis squamata* (Delle Chiaje, 1829)
13. *Astropecten monacanthus* Sladen, 1883	51. *Amphiura (Amphiura) abbreviata* Koehler, 1905
14. *Astropecten polyacanthus* Müller and Troschel, 1842	52. *Amphiura (Amphiura) sexradiata* Koehler, 1930
15. *Astropecten vappa* Müller and Troschel, 1843[4]	53. *Amphiura (Felleria) heptacantha* (Mortensen, 1940)
16. *Astropecten velitaris* von Martens, 1865	54. *Dougaloplus acanthinus* (H.L. Clark, 1911)
17. *Astropecten zebra* Sladen, 1883	**Ophiactidae**
18. *Craspidaster hesperus* Müller and Troschel, 1840	55. *Ophiactis affinis* Duncan, 1879
19. *Psilaster andromeda* Sladen1885	56. *Ophiactis helmitiles* H.L. Clark, 1915
Order VALVATIDA	57. *Ophiactis modesta* Brock, 1888
Goniasteridae	58. *Ophiactis savignyi* (Müller & Troschel, 1842)
20. *Stellaster equestris* (Retzius, 1805)[5]	59. *Ophiosphaera insignis* Brock, 1888
21. *Stellaster incei* Gray, 1847[5]	**Ophiotrichidae**
22. *Stellaster princeps* Sladen, 1889	60. *Macrophiothrix aspidota* (Müller & Troschel, 1842)
Oreasteridae	61. *Macrophiothrix bedoti* (de Loriol, 1893)
23. *Anthenea chinensis* Gray, 1840[6]	62. *Macrophiothrix galateae* (Lütken, 1872)
24. *Anthenea pentagonula* (Lamarck, 1816)[6]	63. *Macrophiothrix hirsuta* (Müller & Troschel, 1842)
25. *Anthenea regalis* Koehler, 1910	64. *Macrophiothrix longipeda* (Lamarck, 1816)
26. *Culcita novaeguineae* Müller and Troschel, 1842	65. *Macrophiothrix martensi* (Lyman, 1874)[15]
27. *Goniodiscaster forficulatus* (Perrier, 1875)[7]	66. *Macrophiothrix nereidina* (Lamarck, 1816)[15]
28. *Goniodiscaster scaber* (Möbius, 1859)[7]	67. *Macrophiothrix striolata* (Grube, 1868)[14]
29. *Pentaceraster alveolatus* (Perrier, 1875)	68. *Macrophiothrix variabilis* (Duncan, 1887)
30. *Pentaceraster australis* (Lütken, 1871)[8]	69. *Ophiocnemis marmorata* (Lamarck, 1816)
31. *Pentaceraster gracilis* (Lütken, 1871)	70. *Ophiogymna elegans* Ljungman, 1866
32. *Pentaceraster regulus* (Müller and Troschel, 1842)	71. *Ophiogymna pellicula* (Duncan, 1876)
33. *Pentaceraster sibogae* Döderlein, 1916	72. *Ophiopsammium semperi* Lyman, 1874
34. *Pentaceraster westermanni* (Lütken, 1871)	73. *Ophiopsammium rugosum* Koehler, 1905
35. *Poraster indicus* (Koehler, 1910)[10]	74. *Ophiopteron elegans* Ludwig, 1888
36. *Protoreaster nodosus* (Linnaeus, 1758)	75. *Ophiopteron vitense* Koehler, 1927
Asterinidae	76. *Ophiopteron punctocoeruleum* Koehler, 1922
37. *Asterina sarasini* (de Loriol, 1897)	77. *Ophiothela danae* Verrill, 1869
Asteropseidae	78. *Ophiothrix (Acanthophiothrix) armata* Koehler, 1905
38. *Asteropsis caranifera* (Lamarck, 1816)	79. *Ophiothrix (Acanthophiothrix) spinosissima* Koehler, 1905
Acanthasteridae	80. *Ophiothrix (Ophiothrix) abstinens* Koehler, 1930
39. *Acanthaster planci* (Linnaeus, 1758)	81. *Ophiothrix (Ophiothrix) exigua* Lyman, 1874
Order VELATIDA	82. *Ophiothrix (Ophiothrix) plana* Lyman, 1874
Pterasteridae	83. *Ophiothrix (Ophiothrix) prostrata* Koehler, 1922
40. *Euretaster cribosus* (von Martens, 1867)	84. *Ophiothrix (Ophiothrix) stelligera* Lyman, 1874

Table 3*cont.* Echinoderms found in the Gulf of Thailand.

Ophiocomidae	**Laganidae**
85. *Ophiocoma lineolata* Müller and Troschel, 1842	125. *Laganum decagonale* (de Blainville, 1827)
86. *Ophiocomella sexradia* (Duncan, 1887)[19]	126. *Laganum depressum* Lesson, 1841
87. *Ophiomastix sexradiata* A.H. Clark, 1952[19]	127. *Peronella orbicularis* (leske, 1778)
90. *Ophiarachnella gorgonia* (Müller and Troschel, 1842)	**Astriclypeidae**
91. *Ophiarachnella infernalis* (Müller and Troschel, 1842)	128. *Echinodiscus auritus* Leske, 1778
92. *Ophiochasma stellatum* (Ljungman, 1867)	129. *Echinodiscus bisperforatus* Leske, 1778
Ophiuridae	**Order SPATANGOIDA**
93. *Ophiolepis cincta* Müller and Troschel, 1842	**Spatangidae**
94. *Ophioplocus japonicus* H.L. Clark, 1911	130. *Maretia planulata* (Lamarck, 1816)[22]
95. *Ophiura kinbergi* (Lyman, 1867)	131. *Maretia ovata* (Leske, 1778)[22]
96. *Stegophiura sterilis* Koehler, 1922	**Loveniidae**
ECHINOIDEA	132. *Lovenia elongata* (Gray, 1845)
Order CIDAROIDA	133. *Lovenia subcarinata* (Gray, 1845)
Cidaridae	**Schizasteridae**
97. *Prionocidaris bispinosa* (Lamarck, 1816)	134. *Schizaster (Schizaster) lacunosus* (Linnaeus, 1758)
Order DIADEMATOIDA	**Brissidae**
Diadematidae	135. *Anametalia sternaroides* (Bolao, 1874)
98. *Astropyga radiata* (Leske,1778)	136. *Brissopsis luzonica* (Gray, 1851)
99. *Chaetodiadema granulatum* Mortensen, 1903	137. *Brissus (Brissus) latecarinatus* (Leske, 1778)
100. *Diadema saxatile* (Linnaeus, 1758)[21]	138. *Metalia sternalis* (Lamarck, 1816)
101. *Diadema setosum* (Leske, 1778)[21]	139. *Rhynobrisus pyramidalis* A. Agassiz, 1872
102. *Echinothrix calamaris* (Pallas, 1774)	***HOLOTHUROIDEA***
Order TEMNOPLEUROIDA	**Order ASPIDOCHIROTIDA**
Temnopleuridae	**Holothuriidae**
103. *Paratrema doederleini* (Mortensen, 1904)	140. *Actinopyga echinites* (Jaeger, 1833)
104. *Salmaciella dussumieri* (L. Agassiz, 1846)	141. *Actinopyga* sp. 2
105. *Salmacis bicolor* L. Agassiz, 1846	142. *Bohadschia marmorata* (Jaeger, 1833)[23]
106. *Salmacis sphaeroides* (Linnaeus, 1758)	143. *Bohadschia vitiensis* (Semper, 1868)[23]
107. *Salmacis virgulata* L. Agassiz, 1846	144. *Holothuria (Acanthotrapeza) coluber* (Semper, 1868)
108. *Temnopleurus alexandri* (Bell, 1884)	145. *Holothuria (Cystipus) rigida* Selenka, 1867
109. *Temnopleurus reevesi* (Gray, 1855)	146. *Holothuria (Halodeima) atra* Jaeger, 1833
110. *Temnopleurus toreumaticus* (Leske, 1778)	147. *Holothuria (Halodeima) edulis* Lesson, 1830
111. *Temnotrema siamensis* (Mortensen, 1904)	148. *Holothuria (Lessonothuria) pardalis* Selenka, 1867
Order ECHINOIDA	149. *Holothuria (Lessonothuria) verrucosa* Selenka, 1867
Toxopneustidae	150. *Holothuria (Mertensiothuria) leucospilota* (Brandt, 1835)
112. *Gymnechinus pulchellus* Mortensen, 1904	151. *Holothuria (Metriatyla) albiventer* Semper, 1868
113. *Pseudoboletia maculata* Troschel, 1869	152. *Holothuria (Metriatyla) martensi* Semper, 1868
114. *Toxopneustes pileolus* (Lamarck, 1816)	153. *Holothuria (Metriatyla) ocellata* Jaeger, 1833
115. *Tripneustes* sp.	154. *Holothuria (Metriatyla) scabra* Jaeger, 1833
Echinometridae	155. *Holothuria (Platyperona) difficilis* Semper, 1868
116. *Heliocidaris* sp.	156. *Holothuria (Semperothuria) flavomaculata* Semper, 1868
117. *Heterocentrotus mammillatus* (Linnaeus, 1758)	33. *Holothuria (Stauropora) fuscocinerea* Jaeger, 1833[25]
Parasaleneiidae	157. *Holothuria (Theelothuria) notabilis* Ludwig, 1875
118. *Parasalenia gratiosa* A. Agassiz, 1863	158. *Holothuria (Theelothuria) spinifera* Théel, 1886
Strongylocentrotidae	159. *Holothuria (Thymiosycia) impatiens* Forskål, 1775
119. *Strongylocentrotus echinoides* A. Agassiz, 1863	160. *Pearsonothuria graeffei* (Semper, 1868)
Order CLYPEASTERIDAE	**Stichopodidae**
Clypeasteridae	161. *Stichopus chloronotus* Brandt, 1835
120. *Clypeaster (Coronanthus) latissimus* (Lamarck, 1816)	162. *Stichopus hermanni* Semper, 1868
121. *Clypeaster (Rhaphidoclypus) recticulatus* (Linnaeus,	163. *Stichopus horrens* Selenka, 1867
Arachnoididae	164. *Stichopus japonicus* Semper, 1868
122. *Arachnoides placentra* (Linnaeus, 1758)	165. *Stichopus naso* Semper, 1868
Fibulariidae	166. *Stichopus variegatus* Semper, 1868[27]
123. *Fibularia acuta* Yoshiwara, 1898	***Order DENDROCHIROTIDA***
124. *Fibularia angulipora* Mortensen, 1948	**Cucumariidae**

Table 3*cont.* Echinoderms found in the Gulf of Thailand.

167. *Cercodemas anceps* (Selenka, 1867)[28]	182. *Stolus buccalis* (Stimpson, 1855)
168. *Colochirus quadrangularis* Troschel, 1843[29]	183. *Stolus conjugens* (Semper, 1868)
169. *Cucumaria frondosa* (Gunner, 1767)[30]	184. *Thyone okeni* Bell, 1884
170. *Mensamaria bicolumnata* (Dendy and Hindle, 1907)	**Caudinidae**
171. *Mensamaria intercedens* (Lampert, 1885)	185. *Acaudina leucoprocta* (H.L. Clark, 1938)
172. *Plesiocolochirus australis* (Ludwig, 1875)	186. *Acaudina* sp.1
173. *Pseudocolochirus* sp.	187. *Acaudina* sp.2
Sclerodactylidae	188. *Paracaudina chilensis ransonnettii* (Müller, 1850)
174. *Cladolabes schmeltzii* (Ludwig, 1875)	**Molpadiidae**
Phyllophoridae	189. *Molpadia roretzi* (von Marrenzeller,1877)
175. *Havelockia versicolor* (Semper, 1868)	**Synaptidae**
176. Phyllophorus (Phyllophorella) kohkutiensis Heding and Panning,	190. *Opheodesoma australensis* Heding, 1931
177. Phyllophorus (Phyllophorella) robusta Heding and Panning, 1954	191. *Opheodesoma grisea* (Semper, 1868)
178. Phyllophorus (Phyllothuria) cebuensis Heding and Panning, 1954	192. *Opheodesoma lineata* Heding, 1928
179. *Phyllophorus* sp.	193. *Synaptula recta* (Semper, 1868)
180. *Selenkiella malayense* Heding and Panning, 1954	194. *Synaptula* aff. *virgata* (Sluiter, 1901)
181. *Selenkiella siamense* Heding and Panning, 1954	***Total: 194 species***

Table 4 Endangered and threatened species found in the Gulf of Thailand.

Common name	Scientific name	Status
Sittang whale	*Balaenoptera edeni*	CR
Irawaddy dolphin	*Orcaella brevirostris*	CR
Humpbacked dolphin	*Sousa chinensis*	CR
Bottlenose dolphin	*Tursiops aduncus*	CR
Common dolphin	*Delphinus capensis*	CR
Rough-toothed dolphin	*Steno bredanensis*	CR
Spotted dolphin	*Stenella attenuata*	CR
Malonheaded whale	*Peponcephalus electra*	CR
Shortfined pilot whale	*Globicephala macrorhynchus*	CR
Killer whale	*Orcinus orca*	CR
False killer whale	*Pseuorca crassidens*	CR
Finless porpoise	*Neophocoena phocoenoides*	CR
Dugong	*Dugong dugong*	EN
Whale shark	*Rhincodon typus*	EN
Hawkbill turtle	*Eretmochelys imbricata*	EN
Green sea turtle	*Chelonia mydas*	EN
Loggerhead turtle	*Caretta caretta*	EN
Giant clam	*Tridacna* spp.	EN
Total	**18**	

Note: CR = Critically endangered, EN = Endangered, VU = Vulnerable.